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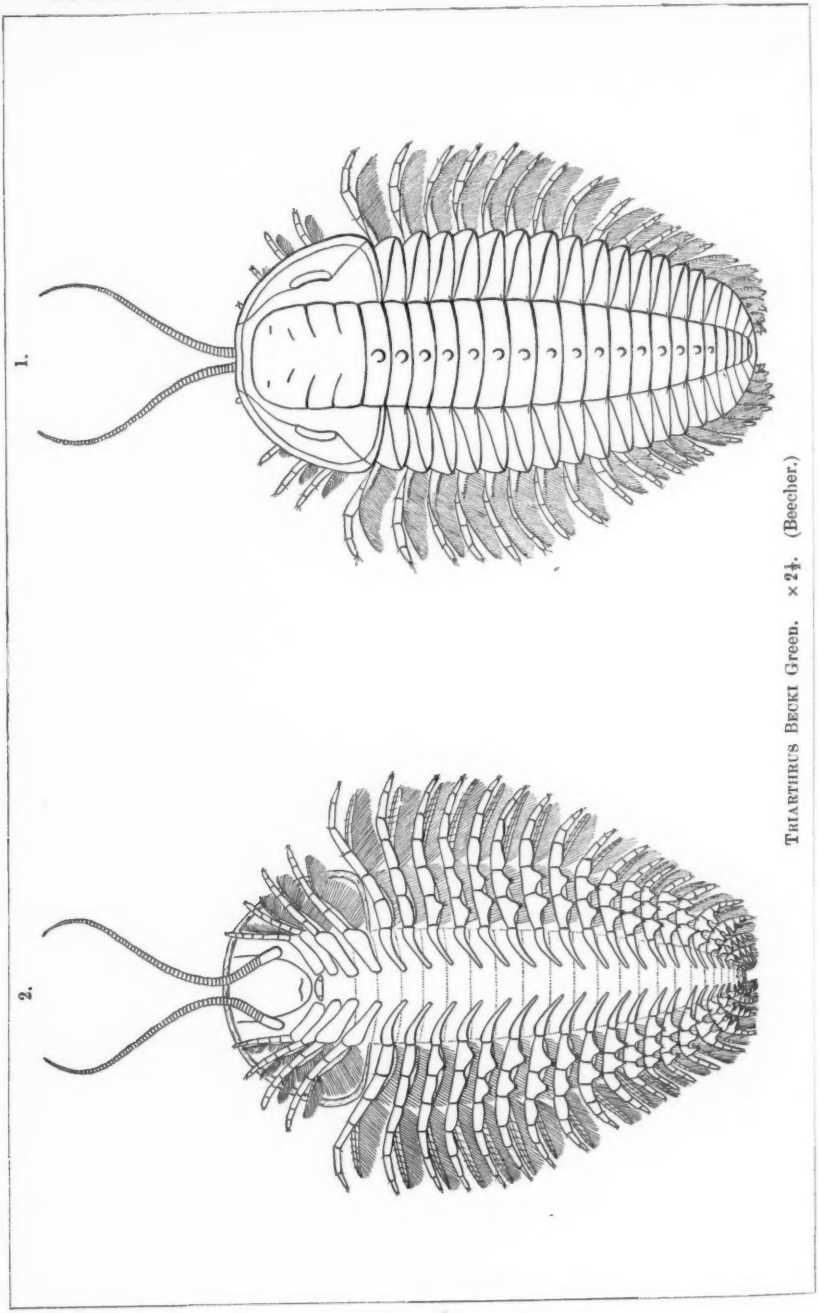

TRIARTHRUS BECKI Green. ×2½. (Beecher.)

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXIX.—*The Morphology of Triarthrus;* by C. E. BEECHER. (With Plate VIII.)

MOST of the recent advances in the knowledge of trilobite structure have come from the study of *Triarthrus*. Since Valiant's discovery of the antennæ, and its announcement by Matthew in 1893, the writer has published a series of papers on the detailed structure of this trilobite. Much time has also been spent in carefully working out the numerous specimens from the abundant material in the Yale Museum. Altogether upwards of five hundred individuals with appendages more or less complete have been investigated; and at the present time, it may safely be said that the important exoskeletal features have been seen and described.*

Notwithstanding the amount of information regarding the details of the various organs, very little has been shown illustrating the general appearance of the animal with the appendages in a natural and lifelike position, and it is one object of the present article to supply this deficiency.

Several specimens have been lately developed which preserve not only the appendages in great perfection, but also show them extended and disposed in a very lifelike manner. No new structural points are here brought out, yet the representation of the complete animal serves as a summary of present knowledge, and also gives a definite picture of great assistance in forming a conception of general trilobite morphology.

* The more important literature relating to the structure of the genus *Triarthrus* is given at the end of the present article; numbers in the text refer to this.

The dorsal view represented on Plate VIII is from a camera drawing based upon three specimens of about the same size. One gives the entire series of legs down to the ninth free segment, with the exception of the exopodites of the head, which are supplied from a second individual. In the third specimen, the anterior appendages are bent and irregularly arranged, while from the ninth backward to the end of the pygidium they are complete and uniformly extended. The figure is, therefore, a restoration only in so far as representing the best portions of three individuals.

The ventral view, Plate VIII, is based mainly upon two very excellent specimens. One was figured on Plate IV, vol. xv, of the *American Geologist*, and another, since found, nearly completes the ventral aspect. The under side of the head and pygidium was carefully compared with all the available material, and no attempt was made to supply any characters except as to the exact number of joints in the endopodial cephalic elements and the precise form of the cephalic exopodites, which from every character observed, and from analogy with similar structures elsewhere, were as represented.

So many specimens preserve the appendages in the position shown in the figures, that this must be recognized as natural and one likely to have been assumed by the living animal when extended. Few, however, show the details of the limbs with sufficient clearness to enable one to make out all their joints, and more minute characters.

In comparison with what is now known of the appendages of several other genera of trilobites, especially *Trinucleus*,* those of *Triarthrus* seem to have been exceptionally long. On this point Bernard, in a letter to the writer, suggests that "*Triarthrus* must have been a sort of 'Daddy longlegs' among the Trilobites, as *Scutigera* is among the Myriapoda." The entire length of a thoracic leg, including the coxal joint, is nearly equal to the width of the body at that point, and about half the length projects beyond the pleura.

The limbs of the head diminish in length forwards until the anterior pair scarcely extends beyond the border of the cephalon. The anterior thoracic legs are the longest, and there is a gradual shortening backward in the series, especially noticeable after passing the fifth, those at the extremity of the pygidium being about one-ninth the length of the first thoracic leg. Their position is also of interest. At the posterior extremity they point almost directly backwards, while those on the head are directed more or less forwards. Between these two extremes, all the intermediate positions occur in regular order.

*Structure and Appendages of Trinucleus, C. E. Beecher. This Journal, vol. xlix, April, 1895.

The gnathobases, or coxopodites, become more and more specialized anteriorly, growing broader and having their inner edge denticulate, until on the head they function as true manducatory organs. The second pair, however, corresponding to the mandibles of higher crustacea, has not become clearly differentiated from the rest of the series, and apparently has not lost the exo- and endopodial branches.

Few changes of importance can be traced in the exopodites, though the latter are considerably reduced in size on the cephalon. Over the anterior half of the thorax, they functioned as vigorous paddles, and on the pygidium their length and compact arrangement made them overlap each other, thus producing two broad flaps, or fin-like organs. The conclusion cannot be avoided that *Triarthrus* must have been an active creature, and with its rows of endopodites and exopodites it was as fully equipped as the bireme in classic navigation. The form of the animal and the multiplicity of locomotor organs were well adapted for rapid motion either along the sea-bottom or through the water.

The youngest and most immature limbs are on the pygidium, and in a young trilobite they are very much like those in the larval *Apus*[4] and are typically phyllopodiform. According to the law of morphogenesis, these limbs may be taken as of phylogenetic value and indicative of the primitive type of limb structure.

The whole series of endopodites anterior to the last two or three show modifications from the phyllopodous type, the change involving progressively from one to all of the endites. The endopodites of the pygidium have a true phyllopodiform structure, and are composed of broad leaf-like joints, wider than long. This character is gradually lost in passing anteriorly, the distal endites being the ones first affected. By the time the anterior pygidial limb is reached, the three distal joints are longitudinally cylindrical. The ninth thoracic endopodite shows a fourth endite becoming cylindrical, and on the first and second thoracic legs even the proximal ones are thus modified, making all the endites of these limbs slender in form.

This gradual modification of a phyllopodiform swimming member into a long, jointed, cylindrical, crawling leg deserves more than passing notice, for here, probably, better than in any known recent form can the process and its significance be studied. No living type of crustacean more nearly conforms to the theoretical archetype of the class than do the trilobites, and as *Triarthrus* belongs to an ancient Cambrian family, it may be expected to retain very primitive characters.

In this genus several causes evidently influenced the modification of the appendages. First may be mentioned the speciali-

zation into oral organs of the gnathobases of the head, which would tend toward a reduction of the other portions of the limbs. Next, the assumption of a walking habit would gradually lead to a corresponding adaptation of the anterior thoracic endopodites, this region of the body being naturally the place where they would be most operative. Lastly, any tendency to change the form of the anterior limbs would be accelerated through the greater number of moults they undergo as compared with the abdominal appendages.

Since the anal segment of crustacea contains the formative elements out of which all the trunk segments are successively developed, it may be considered as the same segment in all crustacea, no matter how many nor what kinds of segments may intervene between it and the head. The youngest segment, therefore, is always in the budding zone, just in front of the telson, or terminal somite, and those further anterior and more differentiated are older. This sequential order in the age of the segments and appendages may be greatly obscured in higher forms, so that, as in the Thoracostraca, the last pair of pleopods, forming with the telson the caudal fin, appears at an early stage of the ontogeny. In such cases, as Lang says, "the grade of development and physiological importance of a section of the body or of a pair of limbs in the adult animal may be recognized by the earlier or later appearance of their rudiments."*

In *Triarthrus*, these disturbing factors are hardly to be recognized, for no pair of limbs had an excessive physiological importance over any other pair or series of pairs, and increase progressed regularly by the addition of new members in front of the anal segment. The pygidium being formed of fused segments accommodated itself to this kind of growth by pushing forward the series of limbs and by the formation of a new free segment at the posterior end of the thorax. This process of metameric growth continued from the protaspis stage with no free thoracic segments, and successively added segment after segment with corresponding moults, until the full complement was reached, after which the moulting resulted mainly in increase in size. The repetition of moults afforded the chief means by which modifications in the appendages could be brought about.

The earliest protaspis stage shows, from the segmentation of the axis, that there were present five pairs of appendages on the head and two on the pygidium.[9] The adult animal has thirteen or fourteen free thoracic segments and six pygidial.†

* Text-Book of Comparative Anatomy, English edition (Bernard), p. 410.

†A few individuals of this species (*T. Becki*) have been observed with one or two additional thoracic segments. Walcott.[11]

Now, so far as is known of trilobite ontogeny, there was never more than one segment added at a single moult, though there is no evidence that there may not have been more moults than segments between the protaspis stage and the finished segmentation. In *Triarthrus*, the average full number of segments was attained by the time the animal reached a length of about 7^{mm}. So that the limbs of the anterior thoracic segment in an individual 7^{mm} in length, and containing the full complement of fourteen free and six pygidial segments, must have undergone at least seventeen moults. The second thoracic segment, therefore, at this stage of growth would have been moulted sixteen times, the fifth thirteen times, the tenth eight times, and the fourteenth four times. The length of full-grown individuals is from 25 to 40^{mm}, and to have reached this size a considerable number of additional moults must have occurred, in which all the segments participated alike.

Some mention should be made of the probable method of respiration of *Triarthrus*. No traces of any special organs for this purpose have been found in this genus, and their former existence is very doubtful, especially in view of the perfection of details preserved in various parts of the animal.

The delicacy of the appendages and ventral membrane of trilobites and their rarity of preservation are sufficient demonstration that these portions of the outer integument were of extreme thinness, and therefore perfectly capable of performing the function of respiration. Similar conditions occur in most of the Ostracoda and Copepoda, and also in many of the Cladocera and Cirrepedia, where no special respiratory organs are developed.

The fringes on the exopodites in *Triarthrus* and *Trinucleus* are made up of narrow, oblique, lamellar elements becoming filiform at the ends. Thus, they presented a large surface to the external medium, and partook of the nature of gills. But, as Gegenbaur says, "the functions of respiration and of locomotion are often so closely united that it is difficult to say whether certain forms of these appendages should be regarded as gills, or feet, or both combined."* For purposes of locomotion, the limbs of the cephalon and pygidium were of feeble assistance compared with those on the thorax, and in the higher crustacea, these two regions are the ones where the greatest branchial specialization takes place.

Yale Museum, New Haven, Ct., February 24th, 1896.

* Elements of Comparative Anatomy, English edition (Bell and Lankester), p. 241.

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EXPLANATION OF PLATE.

FIGURE 1.—*Triarthrus Becki* Green; dorsal view; showing character and extent of antennules and limbs beyond the carapace. × 2½.

FIGURE 2.—*Triarthrus Becki* Green; ventral view; showing entire series of appendages, together with hypostoma, metastoma, and anal opening. × 2½.

Utica Slate, Ordovician, near Rome, New York.

ART. XXX.—*An examination of the arguments given by* NEUMAYR *for the existence of climatic zones in Jurassic times;* by ARNOLD E. ORTMANN.

IN a recent publication (Principles of marine Zoogeography)* the present writer incidentally indicated the reasons why Neumayr's theory of climatic zones in the Jurassic period cannot be accepted as correct. It may be allowed to enter into details in the present article, since my views differ so widely from these of Neumayr, and especially since many prominent geologists have adopted his views more or less completely.

It is very important to examine closely the arguments of Neumayr himself and his defense against the objections made by other scientists. Although the arguments are collected in a special paper (1883), the detailed palæontological investigations and the conclusions derived from particular cases are scattered through a large number of publications, and therefore it would be perhaps desirable to give here a list of the papers referred to.

1871. Jurastudien, 5. Der penninische Klippenzug.—Jahrb. K. K. Geol. Reichsanstalt, vol. xxi, p. 503–526.
1876. Die Ornatenthone von Tschulkowo und die Stellung des russischen Jura.—Benecke's geogn. palæont. Beitræge II.
1877. Bemerkungen über den russischen Jura.—Neues Jahrb. Min. Geol. Pal. 1877.
1883. Ueber Klimatische Zonen wæhrend der Jura—und Kreideperiode.—Denkschr. K. K. Akad. Wiss. Wien., vol. xlvii.
1885. Die geographische Verbreitung der Juraformation.—ibid., vol. l.
1887. Ueber die Beziehungen zwirchen der russichen und westeuropäischen Juraformation.—Neues Jahrb. etc. 1887, 1. †
1890. Kritische Bemerkungen ueber die Verbreitung des Jura.—ibid. 1890, 1.
1890. Erdgeschichte, vol. II.

The supposition, that in the Jurassic time climatic zones were developed on the earth, was first made by Marcou, but it attracted no attention until Neumayr attempted to prove this theory by palæontological and geological evidence. The demonstration given by him proceeds in the following manner.

He investigated the different faunas, especially of the middle and upper Jura in the different localities of Europe, and

* Grundzüge der marinen Tiergeographie, Jena, 1896, p. 62. 63.

† This is a reply to a paper under the same heading published by Nikitin in 1886 in the same periodical.

discovered, mostly in the groups of cephalopods, certain peculiarities of distribution, consisting chiefly in the presence of certain genera (*Phylloceras*, *Lytoceras*, *Simoceras*) in the southern European deposits, but wanting or represented only rarely in the deposits of the other parts of Europe. The northern boundary of this southern province, the Mediterranean, follows, generally speaking, the course of the Alps and Carpathian mountains. In the other parts of Europe, the Jurassic deposits of England, France, Germany, Poland, show further differences from those of Russia; the former, the Middle-European province, possesses peculiar cephalopod-genera, such as *Oppelia*, *Aspidoceras*, while in the latter, the Russian province, these are nearly wanting and other animals are here abundantly developed, such as species of the group of *Belemnites excentricus*, and of the Lamellibranchiate-genus *Aucella*.

Neumayr resolved to investigate the causes of these apparent faunistic differences of strata formed at the same times, and his considerations are the following. Such differences may be due either to topographical causes, such as separation of the relative basins by land, or as differences of facies or depth of the sea; or they may be due to climatic causes. Believing further, to have demonstrated the impossibility of the action of such topographical causes as named, he concludes that the only remaining way for explaining the existing differences is by supposing that climatic differences of the sea are responsible for them. This supposition is strengthened, according to him, by the situation of these "provinces," being limited each to a circumpolar zone around the earth.

An investigation of Neumayr's views is therefore divided conveniently into three separate parts: 1. An examination, whether differences of the faunas are really present; 2. An examination, whether the proofs given for the impossibility of the action of topographical causes are sufficient; 3. An examination, whether the circumpolar zones are confirmed in a satisfactory manner.

But, before this, we have to decide a preliminary question: whether the groups of animals investigated by Neumayr give us a guarantee that their distribution is able at all to indicate climatic differences. Further, in conclusion, we will demonstrate that many additional objections can be made to the climatic zones of the Jura, even if their existence is supposed to be granted.

I. The group of animals, the fossil remains of which are most especially studied by Neumayr, and from the distribution of which his arguments are taken, is that of the Ammonites. This group is extinct in the recent seas; the now living

Nautilus only is in some way related to it, but we have reason to suppose that the habits of the Ammonites were generally the same as in Nautilus. From the latter animal recently J. Walther * has inferred a peculiar fact in regard to the Ammonites, namely that the living animals were restricted in their distribution to narrow limits within the littoral district of the sea, but that after the death of the animal the empty shell, provided with air chambers, rose to the surface of the sea and was transported by wind and currents. Thus the shells were dispersed all over the earth and were deposited as fossils in parts where the living animal did not exist. According to this peculiarity, he says that the Ammonites are true "characteristic fossils," as they are to be found in all the deposits of the same time on the whole earth.

This supposition is without any proper foundation, even in case the Ammonites possessed the same habits as Nautilus. The living Nautilus is *not restricted* to a limited range, as supposed by Walther (l. c. p. 513.) It is true, the living animal has been found up to the present time only in a few localities, but even these localities, scattered in the Pacific Ocean,† indicate a more extensive distribution within this area, and I may add, that I have ample reason for believing that the living Nautilus is also an inhabitant of the eastern coast of Africa.‡ This distribution would not be strange; on the contrary, the range of Nautilus would be in accordance with that of the other animals belonging to the littoral Indo-Pacific fauna. Further, the empty shells of Nautilus occur only in the Indo-Pacific Ocean, the statement made by Walther (l. c. p. 513), that their distribution is an universal one, being incorrect, and thus the distribution of the shells does not occupy a wider area than that of the living animal. On the

* Einleitung in die Geologie als historische Wissenschaft II. Lebensweise der Meerestiere 1893, p. 509ff.

† For instance: Amboina, New Guinea, New Hebrides, New Caledonia, Fiji Islands.

‡ During my stay on the east coast of Africa I collected positive information about the existence of living Nautilus near the harbor of Dar-es-Salaam. I was shown two very fresh specimens of the shell, and the owner of one of them told me, without being asked, that he found the shell on the beach after a high tide with an animal inside, which he had much difficulty in extracting. Hearing from me that the animal was a very valuable one, he was sorry not to have preserved it, and farther on, he spent his leisure time in search for another specimen, and that without my knowledge, apparently intending to sell it to me if possible. He was not successful. I trust wholly in the correctness of his information, as I received others from him regarding zoölogical objects which proved to be trustworthy. Later on I found out that the animal is generally known among the negro fishermen living on the beach. According to their own words, it lives "kisiwani," ("among the islands," situated off the coast), and in "maji mingi" ("deep water," for the coast-negro 10 to 20 fathoms are "deep water"). The animal is not rarely captured by them, but it is always thrown away as of no use for them.

other hand, if the alleged transportation of the empty shells of the Ammonites over the seas should be correct, we ought to observe actually a world-wide distribution of the fossil Ammonite-species, but this is not the case. Some species indeed are found in the same zone all over the European Jura, and some of them are found even in extra-European localities, but this fact can never be a proof of the universal distribution of the Ammonites in general. On the contrary, most of the species are found only in limited localities and almost every locality has its peculiar species. Whoever is occupied in determining the different species of Ammonites and is familiar with the systematic diversity of this group, ought to know the local restriction of most of the species.*

Neumayr, on the contrary, is inclined to regard the Ammonites as animals swimming on the surface of the sea, as belonging to the pelagic fauna (see Erdgeschichte, 1890, p. 270). It seems that he was not aware that this supposition is very dangerous to his theory. I do not want to deny that the possibility must be granted, that perhaps some species or genera of Ammonites belonged to the pelagic fauna, as well as that some of them lived perhaps in abyssal depths of the sea; but by the actual distribution of these fossils I am convinced that by far the greatest number of Ammonites lived as benthonic animals in the moderate depth of the littoral, and in this point I agree with Walther (l. c. p. 515). But further I am convinced that they lived even in these places where now their shells are found in the fossil state. It may be that the empty shells could be transported in the manner mentioned, but such a transportation could not take place over large tracts of the seas, and could not be the normal condition of things; otherwise the actual distribution of the species of Ammonites would be entirely different.

From the foregoing considerations we have to conclude that the Ammonites can furnish us with sure evidence for the existence of faunistic differences, as Neumayr has indicated.

I have still to make some remarks on the Reef-corals alluded to now and then by Neumayr. Contrary to the Ammonites, he tries to abate the value of the proof given by the Reef-corals in regard to the former climatic conditions. Generally we are wont to conclude from the recent exclusive distribution of the Reef-corals in the tropical seas, that the fossil Reef-corals also lived in seas of a tropical climate. Neumayr, however, urges on several occasions that we have no sufficient reason for so doing, since Reef-corals may have

* Already Tornquist (Fragmente einer Oxford fauna von Mtaru.—Jahrb. Hamb. Wiss. Anst. X. 2, 1893, p. 24) calls Walther's hypothesis an "incomprehensible" one.

lived in former times in cooler water. In this point, I believe, Neumayr's view is incorrect. We are justified in supposing that animals living in cooler water are to be traced back to such ones living in the tropics in former times, that is to say, the adaptation to a cooler climate is a more recent acquisition. But it is very improbable that animals living originally in cooler water migrated back into the tropics, because they would find there a most dangerous concurrence in the struggle of life by the well adapted tropical fauna, while they themselves were not so well fitted for the tropical conditions. Therefore the stenotherm Reef-corals living nowadays exclusively in the tropics and showing no traces of existence in the cooler seas, were most probably stenotherm tropical animals also in former times. If in any groups of animals, we have surely in the Reef-corals sufficient reason for arguing from the recent conditions to the former ones; especially is this the case in the Mesozoic corals, since these are the direct ancestors of the Tertiary and recent corals.

II. The palæontological foundations of Neumayr's theory, taken principally from the Ammonites, are the following: The Mediterranean province is characterized by the most general and frequent presence of the genera *Phylloceras*, *Lytoceras*, and *Simoceras* in all the cephalopod-beds, and a very peculiar deposit of this province are the Aptychus-beds. Both the genera just mentioned and the Aptychus-beds are either very rare or wholly wanting in the Middle-European province. The latter, however, shows often a local development of Sponge-fields and Coral-reefs, connected with the abundance of certain gasteropods, such as *Nerinea*. On the other hand the genera *Oppelia*, *Peltoceras*, *Aspidoceras*, very frequent in middle Europe, are very rare in the Russian province and the same is the case in the Reef-corals. In the latter province again the genus *Cardioceras*, the group of *Belemnites excentricus*, and certain bivalves, such as *Aucella* (Aucella-beds), prevail.

These differences cannot be overlooked. Nikitin, indeed, attempted to reduce these differences for the Russian Jura, and in some instances, for example as regards the genus *Cardioceras*, he is right (l. c. 1886, p. 232); but his statement, that there prevails an equal fauna throughout the Russian and West-European Jura is at least an exaggeration. According to the lists of fossils given by him, the differences mentioned by Neumayr are certainly present. On the other hand, Nikitin proved the existence of Reef-corals in the Russian province, and although these corals occur only in a few localities, and although Neumayr does not notice properly this point in his

reply to Nitikin's objections, regarding the presence of these animals as not conclusive, we must regard this point as very important, as we shall see below.

III. Neumayr continues in his argument by attempting to prove that these faunistic differences cannot be due to *topographical* causes. First he says that these three provinces could not be separated from each other by land. This relates especially to the limits between the Mediterranean and Middle-European provinces, while for the Middle-European and Russian provinces it was only partially the case. In the latter, at the formation of the Callovien-beds, first there was an open communication of the seas, later, after the Oxford-group, the Russian basin was closed on the west. We make no objection to this part of Neumayr's views.

Further Neumayr says that a second cause of a separation can be found in the different depths of the respective seas. Between the Middle-European and the Russian seas such differences are out of the question, because both were seas of shallow water. Between the Middle-European and Mediterranean provinces, however, differences of depth were certainly present. At least as regards the *Aptychus*-limestones, it is sure and generally accepted, that these peculiar deposits were formed in deep water, and further, Neumayr himself concedes that such a supposition has a "certain probability" (1871, p. 523) also for the subcarpathian and subalpine localities showing the peculiar Cephalopod-beds of the Mediterranean Jura, since the situation of the latter is an intermediate one between the Aptychus-beds on the one side and the Middle-European deposits on the other "formed in considerably shallower water." In spite of this, he believes that this supposition is not justified, since in some localities on the northern border of the Mediterranean province, especially near Stramberg in Moravia, where the Coral-reef facies prevails, among the Ammonites the typical Mediterranean genera, *Phylloceras* and *Lytoceras*, predominate. Therefore he concludes (1871, p. 524): because on certain localities on the northern border of the Mediterranean province corals are found in Cephalopod-beds, differences in depth of the sea cannot be the cause of the faunistic differences of the Mediterranean and Middle-European Cephalopod-beds.

This conclusion is incorrect. From the condition of the Stramberg-strata we learn only, that there is a mixture of the Coral-facies and the Mediterranean Cephalopod-facies.* Neu-

* Mojsisovics stated once (Verhandl. K. K. geol. Reichsanst, 1867, p. 187, 1868, p. 127 and 438) that even in this locality the Cephalopod-beds and the Sponge and Coral-beds are not mixed up, but that the former underlie the latter. But

mayr gives no explanation of this peculiar mixture. Regarding, however, the local position of these beds, quoted by himself, on the narrow limits between the Middle-European and Mediterranean Jura, that is to say, between the deposits formed in shallow water and those formed in deeper water (Aptychus-beds), we must assume undeniably that in this region in question the precipice of the sea bottom must have been situated: *a Jurassic Continental border* must have been present there! Then there are only three cases possible. Either the Mediterranean Cephalopod-facies is present there in shallow water, as Neumayr seems to suppose. Or the Coral-reefs grew there in deep water, which is very hard to believe. Or there was present a third condition; namely, the Cephalopod-beds of Stramberg were deposited like the other Cephalopod-beds of the Mediterranean province in deep water, but the corals and other fossils indicating shallow water did not live there, but were transported thither. Such an occurrence can be imagined the easier, since these beds are situated on the continental border, and if the precipice of the sea bottom was a steep one, Coral-fragments from the Coral-reefs living in an upper level, and specimens of the other shallow-water-fauna could roll down to the bottom situated in a lower level and could be deposited in the Cephalopod-beds formed there. That such conditions were actually present in that locality is confirmed by the petrographic nature of the Stramberg-limestone, as described by Böhm (l. c. 660). According to him this limestone often may be called a breccia, and, indeed, respecting one place he says: "Angular, larger or smaller fragments of a light gray limestone are embedded here in a dark gray to pitch black matrix. *The light gray limestone is filled with Corals,*" ("ist von Korallen fœrmlich durchspickt.") *

We need no more evidence for the supposition made here. The conditions of the Stramberg-beds, quoted by Neumayr as adverse to the theory of a formation of the Middle-European and Mediterranean Cephalopod-deposits in different depths of the sea, prove to be a support of this theory when we consider the situation of these beds and their petrographic character.

Besides there is a third topographical cause, which may be held responsible for differences of faunas deposited at the same time: the different characters of the facies. Neumayr alludes to this point only incidentally, and generally he passes over it without giving it due consideration. Concerning the Mediterranean and Middle European provinces he says

this fact lacks confirmation. According to Böhm (Die Bivalven der Stramberger Schichten.—Palæontographica, Suppl. II. 4. 1883 p. 660-662) the different faunas are really found in the same rocks.

* The italics are mine.

directly (1871, p. 521), that there are present palæontological differences between deposits of both "with the development of facies and conditions of formation apparently in complete agreement" ("bei offenbar ganz übereinstimmender Faciesentwicklung und Bildungsverhältnissen"). The facies of these two provinces are, according to him, "apparently" the same, but he does not give any proof for it. It is true, limestone-facies prevail in both, and it may be that Neumayr thought of this fact. There is, however, no doubt that all the known limestone-deposits were not formed under the same conditions; the Coral-limestones and the Cephalopod-limestones of the Middle-European province are certainly different facies; the Aptychus-limestone of the Mediterranean province is characterized by its petrographic nature (Hornstone limestone) due to the presence of silicious matter, and the Cephalopod-limestones of the latter province are also probably different. It is well known that all these deposits are different petrographically, and after a more close, especially microscopical examination, we will be, perhaps, enabled to find out the causes of their differences.

Yet we do not need much to urge these differences in these two provinces, as we saw above that the main differences are given by the different depths of the respective seas. To distinguish the Middle-European and Russian provinces, however, we have to direct more attention to the facies. The differences of the facies in the two latter provinces are wholly neglected by Neumayr, although they were pointed out most vigorously by Lahusen * and Nikitin.

It was a well known fact, even to Neumayr, that in the Middle-European province limestones prevail, especially if we consider the upper strata (1890, p. 316), while in the Russian Jura "more soft clays and sands" (p. 326), and only "in an inferior degree limestones" (p. 327) are found. This prevalence of sandstones, especially in the Aucella beds, is stated by Lahusen several times (l. c. p. 486, p. 491, p. 492), and Nikitin (l. c. 1886, p. 211, p. 237) even holds this peculiarity of the facies responsible for the faunistic differences. It is further a very interesting fact given by Nikitin (p. 217, p. 234, p. 236), that corals are found in some places of the Russian Jura, and these are true Reef-corals belonging to the *Thamnastræidæ*. Neumayr refers (1887, p. 72) to this statement only by saying, that the occurrence of corals in Russia is "very rare," and that (p. 73) against the view that conditions of the facies play part here "grave doubts exist" ("schwere Beden-

* Uber die jurassichen Bildungen im südwestlichen Teile des Gouvernements Rjäsan.—Neues Jahrb. Min. Geol. Pal. 1877.

ken gegenüberstehen").* The statement of Nikitin, however (p. 232), that calcareous deposits are almost absent in the Russian Jura, but that where such are exposed corals are found, induces us to accept a causal connection between the two facts. The occurrences of corals is connected with a calcareous development of the facies, and in the Russian Jura, according to the prevailing sandy nature of the deposits, only local formation of Coral-reefs and limestone-deposits was possible.

The fact that the Aucella-beds are mostly sandy deposits strengthens this supposition so much more, as these beds are wanting in the limestone-facies of Middle-Europe. Thus we are amply justified in looking at the differences in the character of the facies as the cause producing the faunistic differences of the Middle-European and Russian provinces even in the Ammonite-fauna.

By these considerations, I think, I have proved that the argument given by Neumayr for the non-existence or non-action of topographical differences upon the distribution of the Jurassic faunas is a complete failure. Only one point may be granted, that a separation by land was not present in an extensive manner. On the other hand we have learned that it is in the highest degree probable, that on the one side differences of depth of the seas, on the other differences of the facies, are the laws governing the faunistic differences. The first cause applies especially to the distinction of the Mediterranean and Middle-European provinces, the second to that of the Middle-European and Russian (Boreal) provinces.

IV. We have still to examine the third point in Neumayr's argument. As a corroboration of the climatic nature of the differences of the Jurassic faunas, he points to the distribution of the different provinces on the earth, which he alleges to be generally parallel to the equator all around the earth, thus forming circumpolar zones. This is the weakest part in Neumayr's view, especially because most of the extra European Jurassic deposits are very unsatisfactorily known, and because Neumayr himself was already acquainted with some localities contradicting his theory.

Neumayr attributes some significance to the supposed fact, that in South Africa and South America Jurassic deposits are said to be present, corresponding in their characters to the

* In his latest rejoinder to Nitikin (N. J. M. G. P. 1890, 1, p. 142) Neumayr refers to his former paper (1887) as having shown that differences of this kind were not to be held responsible for the faunistic differences. But he did not even attempt to prove this assertion in that paper.

Middle-European features, thus indicating a similar (temperate) zone on the southern hemisphere. But he himself gives different opinions concerning these localities: once (1890, p. 330) he says, that the so-called Uitenhaage-formation, near Port Elizabeth, Cape Colony, has a fauna of Middle-European "habitus," and again (p. 333) he says, that the same formation has relation neither to the tropical African localities nor to those in Europe, while relations to some localities in East India (!) and South America (in the Andes of Chili) are apparent. All we know of the latter locality * is that there are present species of *Phylloceras*, *Lytoceras*, and *Simoceras*, thus showing a more likely relation to the Mediterranean than to the Middle-European Jura, as supposed by Neumayr. At present, indeed, we may better disregard all these localities, as our knowledge of them is very incomplete.

Further, Neumayr himself concedes the Middle-European character of the Jurassic deposits of the Hermon, Syria. This occurrence, so absolutely opposed to his theory of climatic zones, he tries to explain in a very forced manner, supposing arbitrarily a southern local extension of the Middle-European Jura into the equatorial zone. We may add here that the Jura of Cutch, India, is regarded by Waagen as Middle-European, while Neumayr claims it as Mediterranean.

In this respect a recent paper of Tornquist, † treating a Jurassic locality on the eastern coast of Africa, near the equator, is very interesting. Tornquist says (p. 23): "As far as we know the fauna of Mtaru, it must be regarded surely as being of Middle-European character." Thus we would have there, near the equator, a Jurassic fauna, which, according to Neumayr, can only be found in much higher geographical latitude. As the fauna of Mombassa, situated in the neighborhood of Mtaru, shows relations to the East Indian localities, which are according to Neumayr Mediterranean, we have there, on the eastern coast of Africa, Jurassic deposits of either character closely approaching. Further, if we consider that Tornquist makes mention (p. 7, p. 25) of a peculiar facies of the strata of Mtaru, suggestive of the so called "terrain à chailles" in Middle-Europe (limestone-concretions in marl-deposits), we are again led to the opinion that differences of the facies take part in making up the faunistic differences.‡

* See Gottsche, Ueber jurassische Versteinerungen aus der argentinischen Cordillere.—Palæontographica, Suppl. III. 1878.

† Fragmente einer Oxfordfauna von Mtaru.—Jahrb. Hamburg, Wiss. Anst. X. 2, 1893.

‡ We may quote here the following interesting remark of Tornquist (p. 25): "It seems that there is repeated the fact which is known in the Jura of the different countries and which is always equally astonishing, namely, that even over great distances a faunistic agreement of the different zones of the Jura can be accompanied by a lithological one."

The tracing of the different Jurassic zones around the other parts of the earth, especially across the American continent, is so problematic, that it is not worth while to go more into details here.*

The instances, however, given above are wholly sufficient to conclude, that a circumpolar arrangement of the different Jurassic faunas is not yet proved; on the contrary, that some facts are known wholly dangerous to that theory.

V. But even in the case, that it may be granted, that it is neither proved nor refuted, whether the differences of the Jurassic faunas are due to topographical or to climatic causes, and even if we suppose that the action of the latter may have been possible, we will find that such a supposition meets difficulties hard to solve.

1. As we have seen above, Nikitin recognized the presence of Reef-corals in the Russian Jura, that is to say, in Neumayr's *Boreal* zone. Neumayr indeed denies the value of the Reef-corals as evidence for forming an opinion as regards the temperature of the sea water, but as I pointed out above, the Reef-corals are the only group of animals allowing a somewhat sure conclusion as to the former climatic conditions, and I can not strongly enough emphasize that I differ in this respect entirely from Neumayr. Therefore, I am convinced, that the presence of Reef-corals indicates a warm, and especially an equally warm temperature of the seas inhabited, such as now prevails in the tropical seas. If such a temperature was present in the *boreal* Russian basin, we have to ask: what kind of temperature-conditions prevailed in the *temperate* and *equatorial* zones of the Jurassic time? Then we would be induced to believe, that the equatorial seas of the Jura possessed a degree of heat which, compared with the recent conditions, would not have permitted at all the existence of animal life!

2. If we compare the temperature zones of the recent seas† with the supposed temperature zones of Jurassic age as constructed by Neumayr (1890, p. 336), we shall find that the latter are nearly the same as the former, at least as regards their distance from the equator. Even in some cases in Neumayr's map such places belong to a cooler zone, which are nowadays warmer. For instance, New Zealand and Port Elizabeth are situated in his map distinctly in the temperate

* The occurrence of Aucella-beds like the Russian is indicated by Nikitin (Neues Jahrb. Min. Geol. Pal. 1890, II. p. 273) in tropical America, near St. Luis Potosi, Mexico. If this fact should be confirmed, it would prove an additional argument against Neumayr's theory.

† See the map accompanying my book: Grundzüge der marinen Tiergeographie.

zone, while they lie now, if not within the tropical zone, at least on the border of it. An arctic zone can be distinguished in the present seas only with difficulty from the temperate zone: Neumayr's *boreal* zone extends so far southward, that it is hard to believe that it existed at all.

According to our knowledge of the climatic conditions of former times, especially of the Tertiary age, there was a gradual decreasing of the temperature of the earth, beginning at the poles, and we are accustomed to believe that the climatic conditions now prevailing form the most extreme degree of cooling ever present on the earth. Then it would be impossible, that at any time in the past a climate existed which was cooler or was more differentiated than the present climate.* Especially, we can not make such a supposition for the Jurassic age, passed by long ago, and the climatic conditions of Neumayr's map agreeing with the recent ones are utterly impossible. This striking improbability is the more conspicuous as we compare the supposed Jurassic climate of Neumayr with that of the older Tertiary times, as I have already done elsewhere.†

In the passage just referred to I remarked, that Neumayr perhaps intended to express no judgment of the actual temperatures at Jurassic times, but that he had in mind only that a *difference* in temperature was present. But then we would be induced to accept for his boreal zone a climate like that of the recent tropics, and we would be confronted with the same difficulty as discussed under No. 1.

3. Remembering the climatic conditions of the recent times we find, that climatic limits generally are not very sharp, but that there are zones of transition interposed. The limits of Neumayr's Mediterranean and Middle-European provinces are very sharp, so that we can not expect that there prevailed normal conditions. Neumayr himself is aware that these limits are unusually sharp ones, and he explains this fact by supposing that there was a current of warm water present. This supposition, however, is a pure imagination, supported absolutely by nothing.

4. But we will examine this current-theory more closely. Neumayr says (1871, p. 525), that this current coming from the South-West reached in the neighborhood of Cracow its most northern point, and curved then in a south-easterly direction—or the course of this current was in the opposite direc-

* Perhaps one would refer to the conditions of the "ice age" as representing the most extreme cooling: but I remark explicitly, that I regard the so called "ice age" as a local feature of the subrecent time, which is not at all related to the general cooling of the earth.

† Grundzüge der marinen Tiergeographie, 1896, p. 62, 63.

tion. Such a current is according to his map hardly possible. The course in the direction first mentioned is impossible, because no conditions in the configuration of land and sea were present there which could effect a current in this direction (like the Kuro-Siwo and Florida current of recent time). The alleged curve of the current at its most northern point would be also astonishing: why does this current not carry its warm water farther northward into the Russian province? If it went in the opposite direction, we must ask: where did it come from, and what was the cause producing such an abnormal movement of water in a direction never displayed by any important current of the recent seas? And a current effecting such striking and sharp differences of temperatures must necessarily have been an important one!

I think, however, there is no profit in trying to construct the ocean currents of Jurassic age. But if we adopt the configuration of land and sea given in Neumayr's map, there can be no doubt, I believe, that only *one* kind of movement of the surface water of the sea was possible in all these parts under discussion, namely a general current running from East or North-East to the West or South-West. Then from the Russian basin a cool current would run into the Middle-European and Mediterranian provinces, and the course of the northern limits of these two provinces should be very different from that given by Neumayr. These limits could not show a convexity toward the North just opposite the main opening, through which the cool water was discharged, but we should expect a southward curve of these lines.

Under such conditions of things, since it is at present utterly impossible to get an approximate idea of the Jurassic currents, it would be profitable to have recourse to such theories only in the most desperate cases, where no other explanation is possible.

The results obtained by these considerations may be summed up as follows. The differences observed in the faunas of the Jurassic deposits are not caused by climatic differences. The arguments of Neumayr for the non-action of the topographical conditions are partly incomplete, partly they fail to convince. On the contrary, I have shown, that even conditions of the latter kind, differences of depth of the seas and differences of the facies play the chief part in influencing the distribution of the Jurassic fauna, and that the existence of climatic zones in the Jurassic seas is not only not proved, but extremely improbable. Therefore it would be well to abandon entirely Neumayr's theory of climatic zones in Jurassic time,* and it would

* In order to prevent any misunderstanding, I wish to say expressly, that I do not deny the existence of changes in temperature and differences in climate in

be more profitable to examine closely the differences of the facies of this time, especially the question, how the different facies are deposited, and how the different groups of animals are influenced by the facies. There is no doubt that for this purpose we have to compare the fossil deposits with those formed in the recent seas. This latter method is the way outlined by J. Walther in his work: "Einleitung in die Geologie als historische Wissenschaft," and it would be very advantageous to direct more attention to this subject in subsequent geological studies.

Princeton, N. J., January, 1896.

pre-Tertiary times. But such changes and differences of the *ocean-waters* were only slight ones, not differing from those present nowadays within the tropical seas, and not influencing the distribution of animals. On the other hand, the *air-temperatures of the continents* changed even in pre-Tertiary times in proportion to the size of the continental masses to the elevation and to the geographical latitude. Perhaps they did so in a lesser degree than at present, but this difference of the oceanic and the continental conditions of temperatures was almost as striking as it is nowadays between the temperatures of the recent tropical seas and those of the high mountain-chains and table-lands of the tropical parts of the recent continents.

Art. XXXI.—*On an Occurrence of Theralite in Costa Rica, Central America;* by J. E. Wolff.

Among a series of rocks collected by Prof. R. T. Hill in 1895 in a reconnaissance of the Isthmus of Panama and Costa Rica made in coöperation with Mr. Alexander Agassiz, was one small specimen occurring as an intrusion through the Tertiary rocks of the Atlantic slope of the Costa Rican volcanic plateau. Of this specimen Mr. Hill says: "The rock is pushed up through the Upper Oligocene strata [limestone] and hence its age is Miocene or later." According to his diagram, it occurs as a large mass cutting across the bedding of the limestone.

The rock has the typical spotted dark gray color of the Montana theralite with distinct crystals of augite, biotite and rounded areas of radiating zeolites.

In thin section the rock is composed of augite, triclinic feldspar, sanidine, nepheline, a mineral of the sodalite group, olivine, biotite, magnetite, apatite, and abundant zeolites. The augite occurs in imperfect prisms with both pinacoids and terminal planes; it has a pale yellowish-green color with marked zonal structure and an extinction of 43° on the clinopinacoid. In a large section cut across the prism the inner lighter green core has the orthopinacoidal cleavage alone developed, while the outer zones have the usual double prismatic cleavage alone developed, showing an apparent relation between the development of these cleavages and the chemical composition. Ægirine as an outer border or separate from the augite is entirely wanting. The few imperfect crystals of olivine are entirely serpentinized. The biotite occurs in hexagonal plates; the apatite and magnetite require no special description.

The feldspar is the most striking constituent in comparison with the Montana theralite, for the larger part shows multiple twinning on the albite law, with rarely a pericline lamella; even apparent Carlsbad twins are found by optical study to be on the albite law analogous to the well-known occurrence of albite itself in the crystalline schists, and the Carlsbad law seems to be wanting. By means of the Federow universal stage a number of these feldspar sections were brought into the zone of optical symmetry and by revolution on the second horizontal axis the maximum negative extinction of this zone determined at between 26° and 27°*; the feldspar is therefore a labrado-

* The use of this instrument is especially helpful in such cases where the use of the excellent methods of Michel-Lévy (combination of the albite and Carlsbad laws) or of Fouqué (bisectrix sections) is impracticable. Prof. Fedorow has rendered a service to petrographers comparable to that of Goldschmidt, himself and others to crystallography in the invention of the theodolite goniometer.

rite of the composition Ab^1An^1. A few sections of untwinned feldspar have an index of refraction inferior to that of the balsam, a small axial angle, and are therefore probably orthoclase.

The mineral of the sodalite group occurs exactly as in the Montana rock in little crystals enclosed in the feldspar, with a dirty blue color, isotropic character and characteristic square or hexagonal outlines. The nepheline is in small stout square prisms, generally in clusters or enclosed in the feldspar—the usual fibrous decomposition has obscured the original optical properties, but its entire identity in form and characters with the nepheline of the weathered specimens of the Montana rock, leaves no doubt as to its identification. Zeolitization has spread from the nepheline to a large part of the feldspar; most of the zeolites are of the radiating prismatic type, which was not further determined, but there are some patches of analcite.

The main differences from the Montana type are in the absence of ægirine, the distinctly basic soda-lime feldspar and the small amount of sanidine; it probably represents a type poorer in alkalies, but a chemical analysis was considered unremunerative on account of the small amount of material and considerable alteration of the rock. It represents the purest type yet described of theralite as defined by Rosenbusch, namely a soda-lime feldspar-nepheline, plutonic rock.

From the point of view of there lationship of rock magmas this occurrence is extremely interesting, representing as it does a peculiar and rare rock type occurring some three thousand miles from the Montana region, but in a somewhat analogous position both as regards Tertiary age, and location some distance east of the main continental divide. It may be that other occurrences will be found in the future in the intervening region; the nearest representative to theralite known to me in the intermediate distance is the nepheline rock described by Zirkel (in the "Microscopical Petrography of the 40th Parallel") from Fortification Rampart, Elkhead Mts., Colorado, of which more will be said in the forthcoming monograph on the Crazy Mts.

The lack of a chemical analysis makes a comparison from the point of view of identity or difference of rock magmas of less value and weakens the argument which could be based on this occurrence against the localization of rock magmas, while on the other hand it points to a possible southern continuation of the zone of alkaline rocks occurring in the northwestern United States in the east border of the Rocky Mountains.

University Museum, Cambridge, Mass., February, 1896.

ART. XXXII.—*Metamorphism of a Gabbro occurring in St. Lawrence County, N. Y.;* by C. H. SMYTH, JR.

IN the course of a reconnoissance of the crystalline rocks of St. Lawrence County, carried on, during the past summer, for Dr. James Hall, State geologist, the writer examined an area of gabbro which seems of sufficient interest to merit description. The rock affords another indication of the widespread occurrence of gabbro in the Adirondack region, to which attention has been called in a previous paper,* and also shows striking variations in composition and structure, in part primary, but chiefly secondary.

The locality is in the town of Russell, about four miles southwest of the village of the same name, and one-half mile east of the well known danburite locality. The prevailing rock of the vicinity is a massive gneiss, generally with a decided red color. This rock probably bounds the gabbro on all sides, although the limits of the latter were found only on the east and west. The extent in this direction is hardly more than one-eighth of a mile.

It will be convenient to describe, first, the phenomena observed in the field, and then, to consider the petrographic details of the various phases of the rock.

The gabbro and associated gneiss form a short steep ridge, with an elevation of fifty to seventy-five feet, just north of the highway. Even in a rapid examination of the region the gabbro could scarcely be overlooked on account of the marked contrast between its coarser portions and the prevailing country rock. These very coarse parts have a decidedly mottled aspect on weathered surfaces, due to imperfect porphyritic structure, with phenocrysts of feldspar ranging up to three inches in length, surrounded by dark green or black material. A more abundant variety has feldspars seldom extending one-half inch in length, and the porphyritic structure is replaced by a more or less perfect ophitic structure. This phase of the rock may become finer, and may assume a nearly granular structure. At the same time there are variations in the relative proportions of feldspar and ferro-magnesian minerals, with corresponding changes of color. These variations in the rock are all primary and may be summarized as a range in grain from very coarse to moderately fine; in structure from porphyritic to ophitic, and to nearly granular; in color from nearly black to gray. These changes in character take place very suddenly, and

* C. H. Smyth, Jr.—On Gabbros in the Southwest Adirondack Region, this Journal, III, xlviii, p. 54.

the different phases are most irregularly distributed, seeming to conform to no law. The prevailing variety is that having the coarse ophitic structure. In spite of this structure, the rock is classed with the gabbros, rather than with the diabases, on account of its coarseness, the character of its component minerals, and its affinity with other rocks of the region which are undoubted gabbros.

The primary variations in the rock suffice to give considerable diversity to different portions, within a limited area, but this diversity is greatly intensified by certain secondary modifications of structure and composition. As a result of the combined effect of primary and secondary variations, it would be easy to collect, within an area of a few square rods, a half dozen or more specimens whose appearance, even in thin section, would scarcely suggest that they had any connection with one another.

The secondary changes are of two kinds. The first might be classed as degradational in nature, the mineral constituents decomposing, with the formation of reddish masses, blotched with green. These masses are scattered through the unchanged rock very abundantly, and, at first sight, look like inclusions of red gneiss, but on closer inspection they show a less crystalline aspect than the gneiss, being rather inclined to an earthy surface, and they, further, pass by gradual transitions into the gabbro.

The second modification is mainly structural, so far as the megascopic aspect is concerned, but is accompanied by certain peculiar transformations in the minerals of the rock. In this instance the gabbro loses its massive character and passes over into a well developed gneiss, sometimes almost a schist. As the normal structure gives place to a parallel arrangement the constituent minerals assume a more or less rounded contour, and the resultant gneiss is, in consequence, decidedly granulitic. The passage from coarse, massive gabbro into fine, granulitic gneiss, and back into gabbro, is repeated over and over again, and takes place within a few feet. Specimens of the extreme types differ greatly in appearance from each other, and, in the absence of the intermediate phases, would scarcely be suspected of having a common origin.

At several points this gneissoid gabbro shows still another modification of a somewhat peculiar character. This consists principally in the development of platey masses of hornblende, which cut across the foliation of the gneiss at a high angle, approximating, as a rule, a right angle. These plates of hornblende range in thickness up to about half an inch, and extend, interruptedly, for several feet in a horizontal direction. There are no sections to show their vertical extent, but it doubtless

corresponds to the lateral. The plates are parallel with each other, are from one to six inches apart, and occur over areas of several square yards. Wherever this structure is developed, the gneiss has a very peculiar surface. The rock immediately adjacent to the hornblende has been rendered particularly liable to weathering, so that the plates all occupy shallow grooves, separated by corresponding ridges. As a result, the surface of the rock presents an appearance which may be described as similar to that of corrugated roofing. The distance between the grooves corresponds to that between the hornblende plates, their depth reaches an inch or more. As a rule, the plates of hornblende, on account of their resistant character, project slightly above the bottom of the groove.

The grooves, following the hornblende plates, often curve considerably, and when the curves become sharp they commonly pass into small shear zones. In other cases, instead of finding relief along distinct zones, the pressure has crushed masses of the rock into a rather fine breccia.

It is evident that this development of hornblende plates is, like the foliation, a secondary phenomenon. For, not only would it be very difficult to explain as a case of primary banding, but the plates occur only in the gneissoid portion of the rock, showing that their formation has some connection with the gneissoid character. While so much is clear, the precise relation between the platey structure and the foliation is not so evident. The hornblende plates occur in a distinctly gneissoid rock, and make a high angle with the foliation, but they are not themselves affected by this foliation, rather cutting across and interrupting it. The intimate connection between foliation and platey structure, however, indicates that they should be regarded as phases of one period of metamorphism, rather than as resulting from two distinct periods with different conditions.

It may be worth while, in passing, to note the resemblance presented by this phase of the gabbro to a metamorphosed sedimentary rock. In the absence of the massive and transitional portions, the platey structure, with attendant grooving of weathered surfaces, might well be regarded as representing original bedding, crossed at high angles by secondary foliation. There is afforded here an instance of the apocryphal nature of parallel structures in crystalline rocks.

Petrographic Description.

In specimens of the normal gabbro the feldspar is pale gray or purplish, altering to green. The ferro-magnesian constituents are dark green to black, often green in the center with black margins.

Thin sections always show some alteration in the minerals, and this is usually considerable. Where there is an approximation to the original character of the rock, the minerals are plagioclase, pyroxene, magnetite, and titanite as primary constituents, together with a variety of secondary products. Of the two chief constituents, the feldspar is the older, tending to assume a lath shape. It is well twinned, and the lamellæ extinguish at about 25° as a maximum, indicating labradorite. Twinning on the pericline law is often present, in addition to that on the albite law. The feldspar is filled with the fine dust-like inclusions so common in the feldspar of gabbros. It is always largely altered, and is often entirely replaced by secondary products. The most conspicuous of these is scapolite. This mineral generally begins to form on the margin of the feldspar, gradually extending inward until the latter is wholly replaced. On account of this mode of growth, the clouded feldspar individuals are often separated from the pyroxene by a clear zone of scapolite. The mineral is readily recognized by its parallel extinction, strong double refraction, uniaxial figure in convergent light, and negative optical character.

Where the rock shows no effects of crushing, the scapolite is in rather large plates, but in cases where cataclastic structure is present, it is, like the other minerals, reduced to small grains, indicating that it was formed prior to the crushing.

The second product of change in the feldspar is a fine-grained semi-opaque aggregate. This is possibly saussuritic in its nature, but the opacity and extreme fineness combine to render a determination of its constituents impracticable. This method of alteration becomes most conspicuous in the reddish, earthy portions of the rock referred to above.

The pyroxene is colorless, and often contains abundant fine, dark inclusions. The maximum extinction angle observed is 44°. It forms large plates, filling the spaces between the feldspars. It is always more or less changed into deep-green hornblende, usually in irregularly oriented scales. This change begins on the exterior of the pyroxene and extends toward the center. The inward growth may be very regular, showing a central area of nearly pure pyroxene, surrounded by a well defined zone of hornblende. Or, on the other hand, the hornblende may penetrate the pyroxene very irregularly, yielding a network of the former mineral inclosing residual grains of the latter. Usually, a considerable part of the hornblende is oriented parallel with the pyroxene, but there is always an abundance of scales irregularly arranged, and these are not uncommonly in excess. There is invariably some of the hornblende present and it increases at the expense of the pyroxene, up to almost entire replacement of the latter. The

amount of hornblende seems to bear a somewhat peculiar relation to the structure of the rock. Always fairly abundant, even in the most massive specimens, it increases as the rock takes on a cataclastic structure, but as this passes into a distinctly gneissoid structure, the relative amount of hornblende, as compared with pyroxene, decreases.

The other constituents of the normal gabbro, such as magnetite surrounded by secondary biotite, titanite, and rare tourmaline, are of minor importance, and demand no special description.

Of the modifications of the gabbro, only the gneissoid variety requires consideration. While the passage from gabbro to gneiss is gradual, as seen on a large scale in the field, it appears quite abrupt in the microscopic sections, the original structure breaking down rapidly and giving place to the secondary structure. Two types of this secondary structure appear, which, though closely connected, present much difference in thin sections. In the first type, the rock as a whole retains its original structure, the outlines of the different minerals being slightly changed, but all of the constituents are, at the same time, reduced to fine grains, giving a cataclastic structure. As the crushing becomes more intense, the mineral outlines change, and a more or less pronounced parallel structure results. In this stage the rock is a massive gneiss made up of very fine grains of pyroxene, hornblende, feldspar and scapolite. The grains of the two dark and of the two light minerals are aggregated in large masses, so that the rock appears much coarser than it really is.

In the other type of secondary structure, the rock is a well defined gneiss. It is apparently much finer grained than the previous variety, but in reality is coarser, the individual grains being many times larger than in the cataclastic rock, but not aggregated in large patches. The pyroxene and the hornblende do, however, form fairly large masses, but quite different from those described above, being elongated in the direction of the foliation, and often passing around and enclosing the feldspar grains. This rock is composed of feldspar, with pyroxene or hornblende, or, more generally, both. Between this phase of the rock and that with cataclastic structure intermediate phases occur, showing that the development of cataclastic structure is the first step in the process of converting the gabbro into gneiss. The changes which have taken place in the completed process become apparent upon comparing the minerals of the gneiss with those of the original rock.

The feldspar of the gneiss is in equidimensional grains, instead of lath-shaped, and is quite free from the dusty inclusions of the original gabbro feldspar, being water-clear, except when kaolinized. While, in the gabbro, the feldspar is always

well twinned, in the gneiss there are abundant grains, often more than half of the total feldspar, showing no twinning, and, in general, when twin lamellæ are present, they are much broader and less frequent than in the original rock. While some of the grains show extinction angles almost as large as in the gabbro, in most it is from 5° to 15° lower. Adjacent feldspar grains are distinct individuals and evidently not mere fragments of larger individuals.

For these facts, but one explanation seems acceptable: the feldspar of the original rock has been entirely recrystallized, forming again plagioclase, but most of it more acid, while the abundance of untwinned grains points, almost with certainty, to the production of much orthoclase. Moreover, while in the cataclastic variety crushed scapolite is abundant, in the present type this mineral is generally absent. Evidently, metamorphism has changed it back into feldspar, from which it was originally derived.

The pyroxene of the gneiss differs from that of the gabbro in being free from the black inclusions, and in having a deep green color, with faint pleochroism. A difference in form is necessitated by the structure of the rock, and, as above stated, it often builds elongated grains, united to irregular spindles, commonly with parallel orientation over a considerable area. The pyroxene is moulded upon and often encloses the feldspar.

Here again the change in character and in form can be explained only by recrystallization.

The hornblende occurs precisely as does the pyroxene; has lost its scaly form, is often bounded by its cleavage planes, and sometimes by crystal faces, and is rather browner than in the gabbro, with more intense pleochroism. It appears to be the result of recrystallization of the scaly secondary hornblende of the gabbro, this having entirely disappeared.

The gneiss further contains many grains of titanite, the amount of this mineral being much greater than in the unchanged gabbro, where it is a scanty accessory. Two sections show a few grains of epidote. These minerals doubtless formed from materials separated out in the process of recrystallization.

The foregoing facts lead to the conclusion that the extreme effect of metamorphism on the gabbro has been to produce complete recrystallization, yielding a granulitic structure. But in spite of this recrystallization, the mineralogical composition is not greatly changed—feldspar yielding feldspar, pyroxene yielding pyroxene, and hornblende, itself secondary after pyroxene, yielding again hornblende, and some pyroxene. Yet in each case the recrystallization has produced not only changes in external form of the minerals, but also modification of internal structure and of composition.

The relations of hornblende and scapolite to the history of the rock present some points for further consideration. As has been stated, both occur abundantly in the most massive portion of the rock, while the hornblende seems still more abundant in the somewhat crushed portions, decreasing again in the gneiss. The scapolite remains about the same in quantity in the massive and crushed portions, but disappears almost entirely in the gneiss, having been found in only one specimen. In the case of the hornblende it is possible, though not probable, that the relations stated are only apparent, resulting accidentally from the particular set of specimens examined. But as to the scapolite there seems to be no doubt. These phenomena lead to the conclusion that the formation of the scaly hornblende and the scapolite took place under conditions different from those required for the production of the gneiss. The latter is a clear case of dynamic metamorphism, with development of a pronounced parallel structure, and complete recrystallization, the previously formed scaly hornblende crystallizing into larger masses of the same mineral and, partly, into pyroxene as well; while the scapolite is changed back into feldspar. In other words, in the case of these minerals intense dynamic metamorphism has brought about a direct reversal of the earlier process which led to their formation. It is evident that the different varieties of the rock represent different stages of metamorphism, and that the work of the earliest stage is, to a large extent, undone by the latest stage.

The first stage is marked by the formation of scapolite and some scaly hornblende, with little or no sign of crushing, the probable agents of change being pressure, heat and solutions. The latter factor is of importance in connection with the possible addition of chlorine in the conversion of feldspar into scapolite. The familiar theory of Judd* to account for this alteration certainly cannot be applied to the present case, whatever value it may have elsewhere. In the gefleckter gabbro, or dipyre diorite of Norway other writers have pointed out the connection between the alteration of feldspar to scapolite and the apatite veins. The probable derivation of chlorine from the vein-filling solutions has been pointed out, and has been recently accentuated by Vogt† in a lucid manner. In the case under consideration there is an absence of any distinct conduit for chlorine-bearing solutions, and yet it seems possible that chlorine from a deep source may have been carried into the rock by the gradual passage of water under heavy pressure,

* J. W. Judd: On the processes by which a plagioclase feldspar is converted into scapolite, Min. Mag., viii, 1891.

† J. H. L. Vogt: Beiträge zur genetischen Classification der durch magmatische Differentiationsprocesse und der durch Pneumatolyse entstandenen Erzvorkommen, Zeits. f. prakt. Geol., 1895, p. 456.

and probably at a high temperature. The whole question is, however, an obscure one, on which the case under consideration throws no light. At the same time that the scapolite was forming, the conversion of pyroxene into hornblende began. From such a process there would result, ultimately, a rock composed of hornblende and scapolite, which would be massive, but there could not be formed a granulitic pyroxene-hornblende gneiss.

In the second stage, the effects of crushing are pronounced. All of the constituents are granulated, and the rock becomes more or less gneissoid. At the same time the scaly hornblende increases in quantity, seeming to reach its maximum in this phase of the rock.

Finally, in the third stage, the rock undergoes complete recrystallization, the new formed constituents being arranged normal to the pressure that has crushed the rock, and thus producing a pronounced gneissoid structure. In this final product of metamorphism the recrystallization has removed all trace of cataclastic structure. This is a point of some importance in its bearing upon the question of the origin of gneisses, for it shows the uncertainty of one of the criteria which have been used in dealing with this problem. In his valuable paper on the Laurentian of Canada, Dr. Adams* has stated that the gneisses with cataclastic structure are probably igneous, while those lacking this structure have resulted from the crystallization of sediments. While he gives abundant evidence to substantiate this view for the Canadian rocks, the case under consideration shows that this criterion must be used with caution. For here is an example of a gneiss derived from an igneous rock, and yet without a trace of cataclastic structure. There can be no doubt, moreover, that the converse is often true, as there is no reason why the constituents of a rock formed by crystallization of sedimentary material should not be crushed by subsequent pressure, yielding cataclastic structure.

That there have been three such stages of metamorphism, with the results outlined above, seems to follow clearly from the facts observed. As to the scapolite, the history is plain, but in the case of the hornblende the writer accepts with some hesitation the recrystallization into pyroxene, as this is a direct reversal of the common alteration. Still, that such a change has taken place is strongly indicated, and can be doubted only by accepting a remarkable coincidence in the specimens studied.

On comparing the normal gabbro with other rocks of the family in the Adirondack region, it appears to be most closely connected with a gabbro occurring in Pitcairn, St. Lawrence

* F. D. Adams: A Further Contribution to our Knowledge of the Laurentian, this Journal, 1, p. 58.

County, which has been briefly described by the writer.* In composition, and in the methods of alteration of feldspar and pyroxene, there is a close resemblance, but a marked difference appears in the fact that the pyroxene of the Pitcairn rock is distinctly older than the feldspar, approaching a prismatic form; and, further, the feldspar is free of inclusions.

In the ophitic structure, and in the abundant inclusions in the feldspar, the gabbro resembles that of Lake Champlain described by Kemp,† but differs from the latter in the absence of olivine with its attendant reaction rims.

The Russell rock is much more closely connected with both of these gabbros than with any of the diabases of the region, which, with its extreme coarseness and non-ophitic phases, justifies its classification as a gabbro, rather than as a diabase.

But it is in its gneissoid phases that the relations of the rock are of most importance, as they may throw some light upon the question of the origin of the Adirondack gneisses. Light colored, granulitic, pyroxene and hornblende gneisses are quite common in the region, and in seeking their origin the possibility of their being metamorphosed gabbros was early entertained by the writer; but definite facts bearing upon the question have been difficult to procure. These gneisses are closely similar to the gneissoid phases of the rock above described, and while this fact affords no proof of the origin of the pyroxene gneisses in general, it is, to say the least, suggestive, and may well help in further investigation.

Hamilton College, Clinton, N. Y., January, 1896.

Art. XXXIII.—*Notes on Glacial Gravels, in the Lower Susquehanna Valley;* by Harvey B. Bashore.

In this Journal for February, 1894, in describing the Harrisburg Terraces, I mentioned that no evidence of flooded-river action had been observed above the highest gravels then reported at that place, i. e. about 130 feet above the river; and observations since carried on, go far to prove that assertion. It is intended to map out completely the flooded river of glacial times from the southern ice limit to tide water, and to obtain all the facts available in regard to the Lafayette, Columbia and Trenton gravels in this valley, but the rapid approach of cold weather cut short the work for this season.

In view of the vast amount of drainage down the Juniatta from glacial Lake Lesley, considerable work was expended at

* C. H. Smyth, Jr.: Crystalline Limestone and Associated Rocks of the Northwestern Adirondack Region, Bull. Geol. Soc. Am., vi, p. 263.

† J. F. Kemp: Gabbros on the Western Shore of Lake Champlain, Bull. Geol. Soc. Am., v, p. 213.

the mouth of that river. On the left side where it skirts hills several hundred feet high, we found water-worn bowlders about 125 feet above the stream, but no higher.

At the mouth of Losch's run there were gravels and some bowlders on all the adjoining hills up to the height of 125 or 130 feet, but on the land above this altitude there was no trace of flood action. North of this point Dicks Hill—a mountain ridge, 1000 feet high—crosses the valley of the Juniatta and thence continues over the country to the Susquehanna: consequently on this triangular tongue of land extending downward from the mountain, between, and to the junction of the two rivers, we would most readily find the highest flood limit—however high it might be—provided the flood left any record, which it was very likely to do in the still water formed behind the intersection of two such streams. In descending from the mountain, where, it is almost needless to say, we found no "shore lines," we came upon a broad plateau some 250 feet above the river, upon which we found one small bowlder at exactly 200 feet, but it was probably carried there by other means than the action of a flooded river, for nothing more came into sight until we reached a somewhat lower point, where we found a line of bowlders, mostly of Pococo sandstone and conglomerates, stretching from river to river—just about 130 feet above the present channel (341 + 130 = 471 A. T.): here then, most likely, in this ancient "shore line," was left the highest record of the great glacial floods: and a very distinct and remarkable record it is.*

On the Susquehanna, observation was made at the mouth of Clarks Creek and adjoining country—about 30 miles above Harrisburg—but nothing was found above 140 feet, which corroborates the observations which Prof. Wright made several years ago. Investigation has been made concerning all reports of any higher gravels and in every case the gravels were found to be due to other than glacial floods.

The following case is interesting: I was told of presumably high gravels on certain hills west of Harrisburg, in York County, some six miles back of the river.

I visited the place and there, true enough, were the gravels covering almost every field, and the barometer registered 400 feet above the river: but these were not *glacial* gravels.

The bed rock in this locality is a red Trias sandstone, which in some places is literally filled with gravel and small bowlders: to the disintegration of this stone, these gravels were due, although just at that exact locality there was no surface exposure.

One important fact which I have noted in tramping over many miles in this locality is the abrupt termination of all distinct evidence of flooded-river action, at a point about 130 or 140 feet above the present channel.

* In all the high gravel deposits in this locality there occurs some granite—showing glacial origin.

ART. XXXIV.—*The Bearpaw Mountains, Montana.* First Paper;* by WALTER HARVEY WEED and LOUIS V. PIRSSON.

Introduction.—The present paper gives an account of the prominent features of a mountain group in northern Montana. It consists of a cluster of dissected volcanoes whose breccias, tuffs, and flows compose a large part of the area, especially the marginal region; while cores of massive rock and associated dikes and bosses are found cutting soft Cretaceous shales in the central parts of the mountainous tract. The rocks present interesting examples of the differentiation of an alkaline magma, and consist of various types of the syenite family of igneous rocks, together with highly differentiated basic forms that accompany them. The only mention of the geology of the region that we have been able to discover is a brief note by Dr. Waldemar Lindgren,† who examined some specimens of rocks, mostly altered, collected from the southern foot hills by Dr. C. A. White in 1882.

The Bearpaw Mountains form one of the isolated mountain areas that rise abruptly above the grassy plains of central Montana. They consist of a group of peaks and are not a true mountain range, and lie between the meridians of 109° and 110° west, and parallels of 48° and 48° 50′ north. They are situated far to the east of the Rocky Mountain front, and north of the swift flowing Missouri River. The region is readily accessible by a mail stage from Chinook, a town of some size situated upon the main trans-continental line of the Great Northern Railway. The valley lands of the eastern part of the mountains are settled, and there are three post offices in this portion of the region. The western and most highly accidented part lies within the limits of the Fort Assiniboine military reservation.

Topography.—In scenery there is a strong contrast between the billowy, rolling surface of the plains covered with glacial drift and the abrupt slopes and crag crowned summits of the mountainous tract. Several isolated buttes rising above the plain far out from the mountains are genetically connected with them, but will not be considered here.

Seen from the level plains, the mountains present a skyline of more or less conical peaks, in part connected with one another, in part as separate elevations of nearly equal height,

* By permission of the Director of the U. S. Geological Survey. The present paper is based upon notes and collections made by one of the authors (W. H. W.) during a brief visit to the region in October, 1895.

† This Journal, vol. xlv, April, 1893, p. 287.

with one prominent higher point. In reality the mountains do not constitute a chain of hills but an elevated tract 40 miles long and 20 miles broad, dominated by high, prominent peaks, few of which are named. The highest point, known as Bearpaw Peak, reaches an elevation of 7,040 feet above the sea, rising high above the neighboring summits, none of which exceed 6,200 feet in height. Among the Indians this central peak is called Heart Mountain, or literally the Heart of the Mountains. The name of the mountain group is itself derived from the Indian designation for Black Butte near Fort Assiniboine, called by them the Bear's Paw. The mountains of course became known as the Mountains of the Bear's Paw. From Bearpaw Peak the streams radiate in every direction—Clear Creek and Beaver Creek on the east and north, Big Sandy Creek to the west, and Eagle Creek, which runs to the Missouri, on the south, the other streams being tributary to the Milk River. Even the highest and most rugged parts of the region are easily traversed and offer none of the usual risks of mountain exploration.

The mountainous tract is formed of a central group of hills and ridges, coalescing in the western part of the area where they attain their greatest elevation. The eastern half of the mountain area is relatively low in altitude and consists of two chains of hills running east and separated by the broad open valley of Peoples Creek. This valley, which is 3 to 6 miles wide, is a smooth, grassy, alluvial plain sloping very gently from the base of the hills to the stream channel, and is a terrace but little cut by lateral gullies. It is eroded in soft Cretaceous shales, in which there are numerous igneous intrusions. The old outlet of the valley was unquestionably through a wide, flat gap on the southeast side, where the flat terrace level abruptly divides the southern line of hills. The creek meanders quietly through an open bottom with occasional patches of low rose bush, but without trees or even the common willow brush. The mountains on either side are smooth, grassy, somewhat irregular and broken, and show slopes with occasional masses of black or gray volcanic rock projecting above them, conspicuous because of the contrast but not large in amount.

The central part is encircled by a hilly region of much less altitude, whose slopes rise abruptly from the dimpled plain and undulating ridges of moraine covered country, and its northern slopes are covered by forests of pine. Groves of aspen occur also in the highest valleys, and cottonwoods along a few of the streams. Elsewhere the slopes are smooth and covered by a carpet of grass that conceals the rocks, making rapid geological observations impossible.

In topographic features the mountains present a good example of simple sculpture, in which the dendritic system of drainage is but little altered by the marked diversity of rock structure. The region is well watered, but the streams are mostly of small volume and head in perennial springs. With one or two exceptions, they flow rapidly in quiet, meandering courses through grassy bottoms or groves of low willows, show little evidence of spring floods, and are doing but little cutting at the present time. None of them are of the normal torrential type so common in the western mountains.

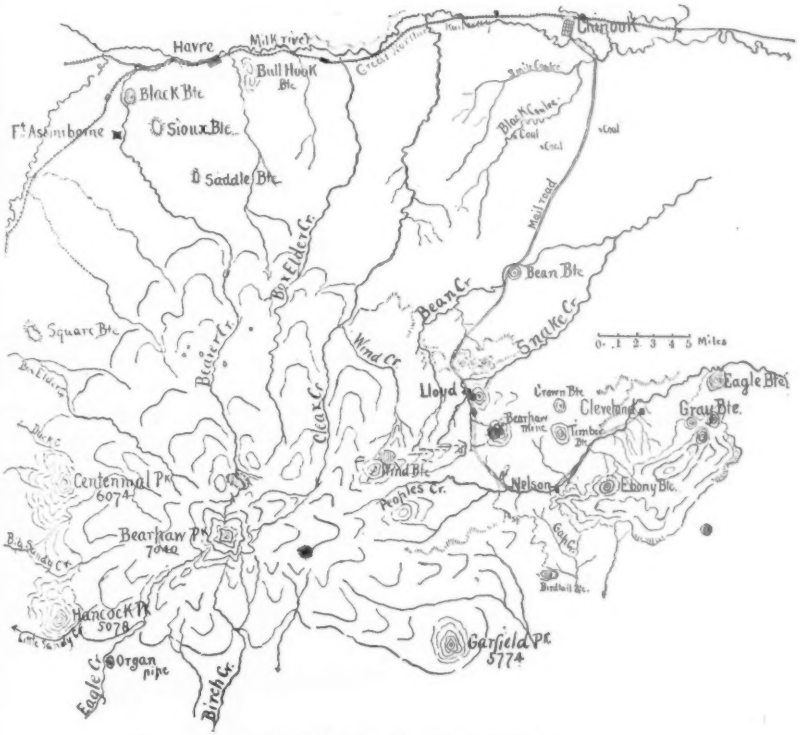

FIG. 1.—Sketch map of the Bearpaw Mts.

Outside of the military reservation the region is settled wherever there are level tracts suitable for cultivation or for the cutting of hay. The heavy growth of grass and the gentle, open nature of the country have been found especially suitable for stock raising.

The highest western point of the mountains is known as Centennial Butte, and the isolated, conical elevation standing at the extreme east end is called Eagle Butte. A few other names in common use among the settlers are given upon the accompanying sketch map.

The mountains have never been surveyed. They appear on most maps of the State, but only the merest approximation to the drainage is given, and the intervening space is filled with meaningless hachures. The accompanying sketch map, compiled from various sources and our own notes, is the best obtainable.

General Geology.

The Bearpaw Mountains are the dissected remains of a group of volcanoes of Tertiary age. Denudation has laid bare the central cores or necks of the old vents, surrounded by altered sedimentary rocks through which the conduits were made. Radial dikes traverse the sedimentary foundation, and accumulations of scoria and various fragmentary volcanic rocks and lava flows form the outer part of the mountain region and also a portion of the central area. The accompanying figure represents a diagrammatic cross-section through the range, showing the stock of granular rock exposed on Beaver Creek and the relations of the effusive rocks to the basal platform of Cretaceous shales. The geology is interesting, not only from these features, which have their counterpart in the neighboring Highwood Mountains, but also on account of the character of the eruptive rocks and the bearing of their occurrence upon the broad problems of petrology. The mountains have not been glaciated, although the confluent terminal moraines of the two great continental ice sheets skirt the flanks on all but the southern sides.

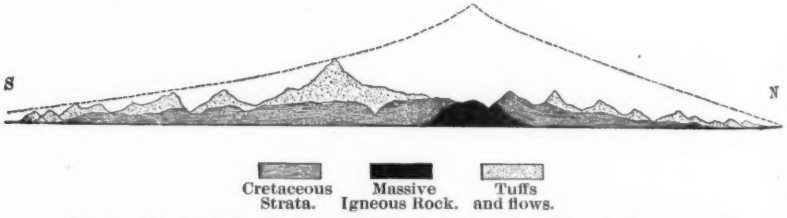

FIG. 2.—North and South section of Bearpaw Mountains through Bearpaw Peak and Beaver Creek Core.

The sedimentary rocks are Cretaceous, and in part at least of Laramie age. They consist of a thickness of 2,000 to 3,000 feet of dark-colored shales, with interbedded sandstones and

occasional lenticular intercalations of impure limestones. So far as observed, the rocks have proved nearly barren of fossils, but as a coal-bearing series occurring along Milk River is also exposed beneath the drift along the stream courses north of the mountains, fossils will probably be found upon a close examination of the beds.* Older Cretaceous strata also occur to the north, near Havre, where they have been identified by Mr. T. W. Stanton, and in the bad lands of the Missouri River, where they have been studied by one of the authors (W. H. W.). About the cores of granular igneous rocks the sedimentary beds are generally highly metamorphosed, more especially where the eruptives are of basic types. In such cases the original character is obscured, and the shales and sandstones are converted into dense, hard hornstones and quartzites of those light-colored, compact and flinty rocks of various shades of lavender, gray, green, and of adinole-like character, which so often characterize the contact zones of igneous intrusions. These baked rocks possess a marked cubical jointing, which causes them to break into small angular fragments, so that imposing exposures are seldom seen. As, however, they often resist erosion better than the granular rocks of the volcanic cores, the contact ring generally stands in bold relief, forming ridges about the igneous centers. Where dikes occur thickly clustered, as is the case on the ridge at the head of Snake Creek, the sedimentary rocks are also much indurated and altered.

From what has already been stated, it is evident that the chief interest in the region lies in the igneous rocks. The unusual character of the types represented make their study of importance, for which reason the field occurrence and the petrographic character are described somewhat in detail.

Extrusive Rocks.

The extrusive rocks are most abundant, forming the highest peaks and many of the lesser summits of the region; they are the usual rocks of the foot-hills, where their richly-colored, rough outcrops form crags and oddly shaped castellated masses in strong contrast to the smooth and grassy slopes about them. They consist of dark-colored basaltic tuffs, breccias and lava flows, which are parts of the former volcanic cones. The finer tufaceous varieties are often washed down and form dark-colored, sandy soils, generally well grassed, while the vesicular slaggy rocks and coarser breccias form

* We have been informed by Prof. O. C. Marsh that the remains of a Dinosaur *Hadrosaurus breviceps* Marsh) described by him (this Jour., vol. xxxvii, p. 335, 1889, also ibid, vol. xxxix, p. 423, 1890), are stated by the collector to have been obtained in the Bearpaw Mountains.

rough masses standing above these slopes. The rugged hills forming the eastern end of the range are largely covered by these crags, whose creamy tints of purple, red, brown, and gray are a striking feature of the scenery.

Within the mountain area the effusive fragmental rocks are quite irregularly distributed. In general they rest upon a formerly eroded surface that was hilly in nature; so that the exposures occur both as cappings to hills and in masses at lower altitudes; no definite bedding is recognizable. The irregular disposition of these masses is well shown in the accidented region between Clear and Beaver Creeks, where the effusive rocks and sedimentary beds are exposed at various altitudes and without apparent order. The rocks of this part of the mountains are, in part at least, more acidic than those generally prevailing, the breccias including fragments of trachytic rocks. The hills in this interior part are smoothly contoured, well grassed, and show the black patches of gravelly debris so characteristic of these basaltic accumulations and which accentuate and bring into strong relief the grassy ridges and intervening hollows. The rocks here also frequently form rough, craggy exposures, almost invariably found upon the southern side of the hills.

In the effusive rocks the breccias predominate, with associated tuff beds and lava flows. The rocks vary from compact, dense basalts showing no porphyritical crystals, to open porous forms which pass into scorias. They have a wide range of colors, red, brown, gray, in warm rich tones, more rarely green and buff. Though varying in appearance they consist almost wholly of leucite basalts; many varieties have no megascopic phenocrysts, but most of them show a dark ground-mass peppered with small white specks of altered leucite, while occasionally crystals of augite are seen, and more rarely olivine. Sometimes the breccias contain blocks of a dense, black rock with large phenocrysts of altered mica. The tuffs vary from pale-buff or dull-green to dark red, brown, or gray in color, and are largely altered.

A specimen selected for examination representing a common variety seen throughout the mountains but coming from Bull Hook Butte, is typical of the rock forming the larger blocks and fragments in the breccias. The rock is of a very dark-gray color, rather compact on the whole, though on jointing surfaces it seems rather porous, and this is probably due to the weathering out of an iron-bearing component; on a completely weathered surface it becomes of a leather-brown color.

On fresh surfaces one readily detects yellowish grains of olivine, passing at times into a chestnut-red color and 1 or 2^{mm}

long, black prisms of augite of about the same size or larger, and round white or very pale greenish grains of leucite, which thickly pepper the dark ground-mass and which vary in size from mere white dots up to 0·5^{mm} across. The rock strongly recalls certain of the south Italian leucite rocks in which the leucite phenocrysts are very small. In thin section the rock is composed of the above minerals thickly crowded, so that there is little base.

The *augite* is of the usual character in rocks of this class; in section it becomes very pale in color and of a brownish rather than greenish tone and has a strong zonal structure, is very idiomorphic, frequently twinned on $a(100)$, has a wide angle of extinction up to 40° or more, shows excellent cleavage and is very fresh.

The *olivine* is generally idiomorphic though occurring at times in polysomatic groups; the large crystals are fresh and clear; the smaller ones frequently changed into a deep-brown or reddish-brown colored substance, which appears to be similar to alterations of olivine seen in other occurrences,* in this change the smaller crystals are completely altered, larger ones only partially, and in the largest the alteration appears only as red-brown bands following cleavage planes. We believe this to be due to a change in the iron oxide in the mineral, and that it is especially iron-rich olivines which are liable to it.

The *leucites* under the microscope are seen to be very thickly crowded, composing the bulk of the rock. They are of all sizes, from very minute individuals up to those previously mentioned. They are of rounded forms though not generally bounded by an absolutely sharp, definite line, but fade out into the ground-mass in a rather ragged indefinite way. They do not contain any of the inclusions zonally arranged which are so frequently seen in this mineral, but are, like the larger leucite phenocrysts in the leucitic rocks, entirely free from them; like these larger phenocrysts they are frequently cracked or appear in grouped polysomatic forms. They are not colorless and limpid like the leucites of the fresh Italian rocks, but are of a light-brown color and appear with a low power very like a kaolinized orthoclase in character; they are perfectly isotropic between crossed nicols. Studied with high powers they appear filled with excessively fine granules, shreds and leaves of some substance so fine that they can barely be discriminated; this material is unevenly distributed through them and does not act on polarized light. It is possi-

* Rosenbusch, N. Jahrb., 1872, p. 59, Phys d. Min., 1892, p. 472; Michel Lèvy, Bull. Geol. Soc. France, 3d Ser. xviii, 1890, p. 831; Iddings, Geol. Eureka Dist., Mon. xx., U. S., Geol. Surv., Appendix B, pp. 388–390; Pirsson, this Journal, vol. xlv, 1893, p. 381; Lawson, Geol. Carmelo Bay, Bull. Univ. Cal., vol i, 1893, p. 31.

ble that it may be original and represents extremely fine inclusions, which, had they been gathered into larger grains, might have arranged themselves zonally. We believe, however, that they really represent a stage of alteration and that the leucites, since they appear so exactly like kaolinized orthoclase, are in fact partially kaolinized. That some alteration has taken place seems possible from the fact that the rock contains over 3·5 per cent. of water, though this in part may well come from the including base. Qualitative tests showed the absence of SO_3 and Cl, and the mineral is therefore not hauyn, nosean, nor sodalite.

The rock appears closely related to the analcite basalts of the Highwood Mountains which have been described by Lindgren,* who showed that in the material studied by him the mineral resembling leucite was really analcite, and from the freshness of the other components he was inclined to regard it as of primary origin. In the course of our own work in the Highwood Mountains we have gathered a large and varied collection of these leucite-like rocks and have found them to consist of several types, and we hope that the investigation which we are now making of them will throw some light on the character and origin of the leucite-analcite minerals. The discussion of these similar Bearpaw types is deferred in consequence until our publication upon this material, which will appear at a later date.

The ground-mass in which the other minerals lie is very small in amount and consists mainly of minute black grains of magnetite, with tiny microlites of augite imbedded in what appears to be a colorless glass.

The composition of the rock from the foregoing is thus shown to be a very simple one—magnetite, augite, olivine, and probably altered leucite. There are no signs of any feldspar present, and the rock is thus a leucite basalt. The occurrence of leucite in this locality we shall have occasion to mention later, in connection with its presence in some remarkably fresh, unaltered, and interesting lavas from Bearpaw Peak.

Intrusive Rocks.

Eagle Butte.—The eastern end of the mountains, near Cleveland, is formed of the sedimentary rocks tilted near the postoffice at angles of 15° to 20° to the southeast, while the prominent buttes seen near by are formed of igneous intrusions of basaltic rocks. The extreme easterly point of the mountains is an isolated conical hill of considerable elevation, called Eagle Butte on the map. It shows a cap of black debris

* 10th Census U. S., vol. xv, p. 719. Proc. Cal. Acad. Sci., Ser. 2, vol. iii., p. 51.

extending downward in tongues cutting the grassy middle slopes. The base of the butte is formed of rough outcrops of purplish, reddish, and steel-colored rocks, with fragments of a light-colored variety which seemed to form a dike or intrusive mass, as seen from the summit of Gray Butte.

The rock is a *mica-trachyte*, having a medium gray color, is of fine grain and filled with many very small glittering black tablets of biotite and with small whitish spots and specks. Under the microscope it appears very badly altered, much more so than the megascopic appearance would suggest. The mica is fresh and recalls that of minettes; there is, moreover, a great deal of it, and it is strongly pleochroic and very idiomorphic.

The rock is filled with masses of calcite, which appears due to the decomposition of augite; some may possibly have been introduced. Secondary quartz also appears filling cavities. There are a number of phenocrysts of feldspar generally showing both albite and carlsbad twinning; one of these, oriented in the zone 001 on 100 perpendicular to 010, gave extinction angles with the Bertrand ocular for the albite twins $a = 19°$ $a' = 19$, the carlsbad twin gave 9°, and hence the plagioclase is andesine. The ground-mass is made up of lath-shaped feldspars, which are so much altered that it cannot be safely told whether a plagioclase which is present or alkali feldspar predominates. The alkali feldspar appears, however, to predominate. It is certainly present, as a little interstitial quartz permits the recognition by Becke's method that some less altered, unstriated granules, have in all positions less refraction than the quartz. The rock appears, therefore, to be a transition form between a *mica-andesite* and a *mica-trachyte* so far as can be told.

Gray Butte is the most western of the isolated group of three elevations, which forms such a prominent feature of the east end of the mountains. Unlike its neighbors it is rugged in appearance, showing bold exposures of massive rock with talus of large blocks covering the slopes below. The lower part for 200 to 300 feet above the base is a steep slope cut in soft black shales that show no fossils and are apparently horizontal. The shaly beds are cut at the southwestern base by a dike of decomposed, hornblendic trachyte. The butte above is formed of an intrusive mass of massive, alkali *quartz-syenite-porphyry*, breaking up through the shales in a boss a half mile wide. The gray color of the outcrops and debris piles which gives the name to the butte is due to lichens, as the rock is a pale-green on fresh fracture, becoming pink on weathered surfaces. The shales are slightly altered for a few yards distant from the contact. The rock occurs in place on the summit of the butte,

where it forms a massively jointed wall extending north and south along its crest, while below large talus blocks cover a steep slope extending down to the top of bold cliffs of the same rock. The cliffs, seen from the surrounding country, form the most noticeable feature of the butte. On three sides they form an almost insurmountable wall, over a hundred feet in height. In these cliffs the syenite-porphyry has a massive, platy structure, the lamination being parallel to the outer surface of the cliffs, dipping on all sides away from the butte at 30° to 45°. Though the rock sometimes breaks along these planes and forms a smooth rock slope, the exposed face of the cliffs is generally much steeper and corresponds to a jointing of the rock. The debris consists of blocks, often 8 feet in diameter, with very little material less than a foot across.

The weathered rock has a botryoidal surface that is rather characteristic. No difference is recognizable between the rock forming these cliffs and that of the summit of the butte, either in the nature or relative amounts of the component minerals, or in the granularity or physical structure. It appears probable, however, that erosion has as yet only exposed the outer part of the boss, and that both summit and side show only the outer portion of the intruded mass.

On a surface of fresh fracture the rock is a very pale-gray color mottled with very pale-pink; on a somewhat weathered surface these contrasts of coloring are accentuated. Upon closer examination the rock is seen to be chiefly composed of large, thickly crowded crystals of feldspar, held in a dense pale-green ground-mass that is speckled with small black augite crystals. The pale-pink tone of the rock is due to these thickly crowded phenocrysts of feldspar. The black augites which occur plentifully scattered through the ground-mass rarely attain a length of 2^{mm}. The feldspar phenocrysts are stout in habit and vary in size from one to one-half centimeter in length. They usually possess the orthoclase habit, are very rarely clear glassy and sanidine-like, and are developed in short, stout, columnar forms on the clino axis; they are apt to be more or less rounded and anhedral.* When idiomorphic they show the common planes $m(110)$, $b(010)$, and $c(001)$. They are frequently carlsbad, less often baveno twins. A few sporadic grains of quartz have also been observed, though they do not appear to be at all common.

* A term suggested for rounded formless masses which do not show outward crystal form. See report of the winter meeting of the Geol. Soc. Am. 1895, in its proceedings, also abstracts in this Journal, p. 150, vol. i, 1896; Jour. Geol. vol. iv, 1896, p. 128. It has been suggested that the terms anhedron and anhedral conflict with allotriomorphic; this is by no means the case, since allotriomorphic is a term of *structure* denoting a formal relation of parts, while anhedron is individual and used in a crystallographic sense.

Under the microscope the rock is found to be composed of *apatite*, *ægirite-augite*, *alkali feldspars* and *quartz*.

The *ægirite-augite* has the usual characters of this mineral; a clear light grass-green color, pleochroism, though not strong, into tones of yellow, an excellent cleavage, and is usually quite idiomorphic. It is zonally built, increasing in the ægirite molecule towards the periphery, and has in these parts a corresponding decrease in the angle of extinction. It has in many cases a pronounced dispersion of the optic axes, which is probably owing to the presence of titanium.

Since the mineral composition of the rock is, as indicated above, so simple, we may reckon out of the bulk rock analysis the chemical composition of this augite, which then has approximately the following composition:

SiO_2	Fe_2O_3	FeO	MgO	CaO	Na_2O
45·3	22·1	1·8	8·6	13·6	8·6=100·0

corresponding in round numbers to two molecules of diopside to one of ægirite.

The *apatite* has been seen only in a very few, rather large, scattered grains; the small amount of it is indicated in the minute quantity of phosphoric anhydride shown in the analysis.

The large *feldspar* phenocrysts between crossed nicols appear homogeneous and in general untwinned, except an occasional carlsbad. In some places areas of kaolinization occur, otherwise they are quite fresh. The cleavages parallel to *b* (010) and *c* (001) are both excellent and furnish good plates for optical examination: such plates parallel to *c* (001) extinguish at about one degree from the trace of *b* (010) while plates parallel to *b* (010) extinguish positively at 10° 30′ to 11° 30′ from the trace of *c* (001) and show in convergent light a positive bisectrix nearly centered in the field. The feldspar is, therefore, not orthoclase but *anorthoclase*, as must indeed be expected from the rock analysis. It seems to be closely related to the cryptoperthite described by Brogger.* A noticeable feature of these phenocrysts is that they contain certain quantities of slender microlites of a striated feldspar. While these are apt to be scattered through the phenocrysts they are especially found arranged in a zone around the edge and projected vertically from the plane faces inward, as illustrated in fig. 3, which shows the phenocrysts and the character of the rock in a diagrammatic way. The great majority of these slender feldspar microlites, no matter how twinned, extinguish parallel to the plane of the nicols or nearly so, and Becke's

*Mineralien der Syenit-pegmatit Gänge, Zeit. für Kryst, vol. xiv, p. 524, 1889.

method shows that they have a higher index of refraction than the anorthoclase in which they lie. They are, therefore, *oligoclase.* Others much more rarely extinguish at angles which reach a maximum of 16° (in sections perpendicular to 010); one of these that gave this maximum showed the exit of a negative bisectrix, and the plane of the optic axes stood at 74° to the trace of 010; the section showed both carlsbad and albite twinning, and both sets extinguish and illuminate nearly simultaneously. This is consequently albite, and Becke's method shows its refraction to be higher than the *anorthoclase.* Thus these microlites vary in composition from albite to oligoclase, the majority being the latter. A closely related occurrence with albite microlites is described by Brogger.* It is thought, in the present case, that the phenocrysts having originally formed at considerable depth were afterwards mostly resorbed, as some of them plainly show by their rounded and corroded forms. An example is to be seen in fig. 3. In the later process of crystallization these were restored and a simultaneous crystallization of the oligoclase took place, the two arranging themselves as seen in the figure.

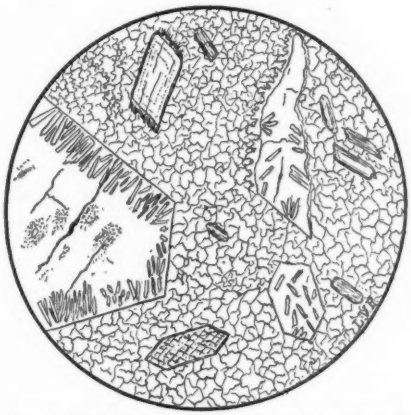

FIG 3.—Syenite Porphyry of Gray Butte, × 14, actual field 4 mm.

The *ground-mass* consists of very small allotriomorphic grains of feldspar with occasional ones of pyroxene. The small feldspar grains are pretty turbid from kaolinization; they do not show any twinning, but with very high powers between crossed nicols they show a mottled, zoned, or flamed appearance in tones of gray and white. Becke's process shows that their refraction is always less than that of quartz, and hence

* Grorudit-Tinguait Serie, p. 17, 1894.

they are various mixtures of alkali feldspars, which agrees with the rock analysis. Nothing definite concerning them could be made out by examination in convergent light.

The *quartz* is clear and limpid and occupies minute irregular areas between the feldspars; a few larger grains were seen. It is small in amount and it does not appear very evenly distributed, some areas being much richer in it than others.

An occasional small *zircon* and one or two scattering *biotite* leaves complete the list of minerals. The rock, with the exception of the slight kaolinization mentioned, is very fresh. An analysis of it, made for us by Dr. H. N. Stokes, in the laboratory of the U. S. Geol. Survey, resulted as follows:

	I.	II.	III.	IV.
SiO_2	66·22	65·54	66·13	64·63
Al_2O_3	16·22	17.81	17·40	18·15
Fe_2O_3	1·98	·74	2·19	3·05
FeO	·16	1·15		
MgO	·77	·98	·04	·50
CaO	1·32	1·92	·81	1·54
Na_2O	6·49	5·55	5·28	5·80
K_2O	5·76	5·58	5·66	4·76
H_2O above 110°	·24	·54	1·22	1·08
H_2O below 110°	·08			
MnO	trace	trace	·13	1·00
TiO_2	·22	·11	·74	?
P_2O_5	·10	trace	?	?
BaO	·29	not det.	----	----
SrO	·06	not det.	----	----
SO_3	·02	----	----	----
Cl	·04	----	----	----
Fl	trace	----	----	----
Li_2O	trace	trace	----	----
	99·97	99·92	99·54	100·54
O=Cl	·01			
	99.96			

I. Quartz-syenite-porphyry, Gray Butte, Bearpaw Mountains, Montana. H. N. Stokes, anal.

II. Quartz-syenite, Highwood Peak, Highwood Mountains, Montana. L. V. Pirsson and W. L. Mitchell, anal.

III. Porphyritic quartz-syenite, near Thinghoug, So. Norway, G. Särnström, anal. (Brögger Min. Syenit pegmatit gänge, 1889, p. 46.)

IV. Quartz-syenite (dike), Fourche Mountains, Ark. R. N. Brackett, anal. (Igneous Rocks of Ark., J. F. Williams, Rep. State Surv., 1890, vol. ii, p. 96.)

This analysis shows very clearly the alkaline character of the rock and its low lime, iron and magnesia. The chlorine and fluorine are in the small amount of apatite. The sulphur shown must come from the traces of sulphide ores present; the titanic oxide is probably mostly present in the augite; a little titanite may be present, but has not been seen. The barium and strontium are probably present in the feldspars. The small amount of water shows the freshness of the rock. Its simple mineral composition permits us to calculate from the analysis the proportion of the different mineral molecules which compose it as follows:

Ægirine augite	8·9
Orthoclase	34·4
Albite	48·5
Anorthite	1·7
Quartz	6·5
	100·0

The amount of the anorthite molecule is a trifle too large, the small quantity of lime required to form the apatite not having been deducted. The augite would have the composition previously given.

For purposes of comparison some analyses of quartz syenites from other parts of the world have been quoted. (The one quoted from Highwood Peak is from a report in preparation by the authors on the mountain group of that name.) These are all quartz-alkali syenitic rocks and they belong to Brogger's Åkerite group.

The contact form of this Gray Butte syenite is fine-grained and resembles the dike rocks of the district. The actual contact was not observed owing to the great amount of talus, but the contact form and the flinty, hardened shales showed its proximity. The rock from the contact is very fine-grained and dense; it appears exactly like the ground-mass of the main type and has the same pale grayish-green color. The most noticeable feature is the almost entire lack of the large feldspar phenocrysts which in the main type are so thickly crowded together and which make so characteristic a feature of the main rock. Occasional feldspar phenocrysts occur, but they are rare, mostly quite small in size, and do not present very sharp boundaries. The little black prisms of augite are the same in size as before, but somewhat less in quantity.

Under the microscope the contact form is precisely like the main type previously described; it consists of the same minerals—ægirine-augite, alkali feldspars, and quartz. The structure is the same only the grain is somewhat finer. The only

noticeable difference is that which is so striking megascopically, the lack of large phenocrysts; a few indeed do occur and they are similar to those previously described but are comparatively very small.

The most interesting feature then of this contact form is the sharp contrast between its almost total lack of feldspar phenocrysts, with the main type in which they occur in such great size and profusion. *It shows clearly that these phenocrysts are not of intratelluric formation*, since in that case they should occur in both forms alike, but that on the contrary they have developed by far the greatest part of their bulk during the final period of consolidation, and thus confirm the ideas concerning their formation previously expressed. Such facts are of great importance to a proper understanding of the porphyritic structure, and the present case is a confirmation of the observations of Cross,* who has thoroughly discussed the bearing of such facts on theoretical petrology.

Cleveland Butte.—The summits south of Cleveland are probably formed mainly of the effusive basaltic rocks, as is shown by the character of the stream drift from their slopes, but massive rocks also occur. The summit forming the eastern end of the range of hills south of Cleveland shows an intrusive rock that differs from those described.

The rock is a *trachyte* of a medium gray color, with a somewhat waxy greenish tone. It is thickly spotted with small prisms of black hornblende of varying size; they are rather slender and average 1 to 3^{mm} in length; occasionally they are much larger, and exceptional individuals a centimeter or so long are sometimes seen; quite rarely irregular or stellate aggregations of them occur. Feldspar phenocrysts are rare; they are 1 or 2^{mm} in diameter. The dense, greenish-gray, feldspathic ground-mass and the hornblendes give the rock its prevailing character. It weathers with a brownish crust.

In the section the *hornblende* is found to be generally idiomorphic but always more or less resorbed and coated with borders of black opacite grains; in some cases this process has gone so far that nothing is left of the original crystal but a mass consisting of black ore grains, shreds of brown biotite and granules of diopside mixed with fibres and masses of the original hornblende. The mineral is of the usual olive-green character with pleochroism into yellowish tones; it has the small angle of extinction and rather low birefraction so commonly found in rocks of this class.

The other prominent ferro-magnesian mineral is a pale-green *diopside*, which is pretty freely sprinkled through the ground-

* Laccolitic Mountain Groups, etc., 14th Ann. Rep. U. S. Geol. Surv. for 1892–1893, p. 228 et seq. Washington, 1895.

mass in well formed crystals which average a smaller size than the hornblende. Unlike the latter it is always fresh and unaltered.

The phenocrysts of *feldspar* are too small and occasional to furnish good material for optical study. In the section they are unstriated, untwinned, and have the mottled, varied appearance between crossed nicols so often seen in anorthoclase. One section of the few that were found was cut near to the face *b*(010), the feldspar was not zonal in its growth but full of irregular areas having varying birefraction and different extinction angles; the direction of the base *c*(001) unfortunately could not be determined, but contacts with quartz show that generally quartz has a higher index of refraction; in one or two areas it did not. We cannot say positively what the character of the feldspar is, but we believe it to be anorthoclase with included areas of an untwinned lime-soda variety.

The phenocrysts lie in a very fine-grained *ground-mass* of alkali feldspar in allotriomorphic interlocking grains, with here and there a very little quartz. It is plentifully dotted through with minute ore grains, and the feldspar is somewhat turbid from kaolinization.

The small feldspar grains of this ground-mass show characters similar to the larger phenocrysts; they have the same patchy, mottled appearance and are untwinned, save for an occasional example after the carlsbad law. They offer only confused images in convergent light, and it was found impossible to orient and determine them. The contacts with quartz, however, show that their refraction is that of the alkaline feldspars, and they are undoubtedly varying mixtures of the albite and orthoclase molecules.

Nelson intrusives.—Near Nelson P. O. there are two buttes which form prominent land marks of the mountains. To the south Ebony Butte is a conical summit with a black cap of debris, while to the north Timber Butte rises high above the valley slopes. This hill is surrounded by an annular ridge with intervening hollows. The debris from the ridge shows it to be a decomposed trachytic rock. A dike of what seems to be the same rock forms a wall exposed on both sides of the creek. The rock is a *trachyte* of a pale brownish-gray color; it is thickly speckled with rusty phenocrysts of a more or less decomposed ferro-magnesian mineral, and occasional large tabular plates of biotite.

The thin section shows numerous phenocrysts of *augite*, *mica*, *oligoclase*, and *orthoclase* in a very fine ground-mass of alkali felkspar with a little quartz. The phenocrysts of augite and biotite are almost entirely altered by decay into serpentine, calcite, chlorite, and ferruginous products, probably

mostly limonite. The augite, indeed, has not been actually seen, but its former presence is inferred from the shape of pseudomorphs consisting of serpentine and calcite. The feldspars are much fresher but have also been attacked by decay, and are pretty turbid from kaolin leaves. The oligoclase whose presence is inferred from the constant practically parallel extinction of albite and Carlsbad twins in the zone 100 on 010 perpendicular to 010, is not very common and appears only as a phenocryst. The orthoclase phenocrysts are much more common and they appear to contain an admixture of the soda molecule, as is usual in these rocks.

The ground-mass in which the above lie is extremely fine-grained, allotriomorphic, and with the exception of a little residual quartz wholly of feldspar, which is untwinned and an alkali feldspar and not an untwinned plagioclase, the presence of the quartz permitting its determination by Becke's method.

People's Creek Basin.—Just above Nelson, People's Creek has cut through a sheet of dark-colored minette-like rock, whose grotesque erosion forms of 3 to 4 feet in height are seen standing in relief upon the grassy bench. This rock contains a large amount of mica, making it a readily recognizable type, but it yields quickly to atmospheric agencies and crumbles to a fine sandy debris. Fresh, unaltered material is very hard to obtain, and although the rock is a common one in the mountains good exposures of fresh rock are very rarely seen.

In the center of People's Creek basin there is a short but very striking dike-like ridge, standing abruptly above the gentle, grassy, gravelly terrace slopes. The rock weathers in huge blocks of pinkish or flesh color, resembling granite from a distance. It is much decomposed, and the blocks are covered by a thick decomposition crust so that fresh material could not be obtained for examination, but it is seen to be a feldspathic rock in which biotite is the only prominent phenocryst.

Galena Butte (*Bearpaw mine*).—Northwest of Nelson is the low divide in the northern chain of hills, through which the mail road from Lloyd has been built. East of this divide there is a high summit, whose grassy open slopes crowned by a log shaft house make it a conspicuous object in the landscape. The building has been erected over an ore body of argentiferous galena, in which a prospect shaft has been sunk. The ore body occurs near the margin of an intrusive mass of trachyte, which, as is commonly the case in these mountains, has been deeply cut by the drainage, while the contact zone with its denser rock and rim of hardened sediments stands out in relief, forming the summit of the butte and its most prominent westerly spurs. The main mass of the rock is a trachyte, gen-

erally much altered, in which large crystals of white feldspar occur in a reddish-yellow ground-mass. Good exposures of the intrusive mass are rare even where the slopes are deeply cut by drainage channels, for the prevalent covering of grass, everywhere a feature of the mountains, often conceals even the debris. The rock is a *trachyte* or syenite porphyry which is too greatly altered and decomposed to be of value for petrographic study. It consists of a brownish, earthy, feldspathic, ground-mass filled with limonite and with hollow cavities caused by the weathering and decay of a former iron-bearing mineral. This is thickly filled with feldspar phenocrysts of a thick tabular or short columnar habit about 1^{cm} in greatest length. Its determination as a rock of the alkali class rests upon the character of its contact form.

The contact form of the trachyte is a dark greenish-gray rock thickly crowded with small idiomorphic feldspar phenocrysts of thick tabular form. There is a sprinkling of rather dull, inconspicuous black dots which are either pyroxene or micas.

In the section the great quantity of feldspar phenocrysts is very evident. The great majority are clear and homogeneous, while some show microperthite intergrowths with albite lamellæ. In a section parallel to $b(010)$ shown by its outline, high birefraction and the exit of a positive obtuse bisectrix, the angle β was measured 65° and the extinction was 8° 30′ plus in the obtuse angle β. A section perpendicular to the acute bisectrix a was examined in convergent light, but the hyperbolas were too vague and shadowy for accurate measurement —it was estimated that 2E was over 60° and under 75°. All these facts show clearly that the feldspar is an alkali one, not of the lime-soda group. No albite twinning occurs, but Carlsbad and more rarely Baveno twins were seen. The measurements would point to the orthoclase nature of the feldspar, but it unquestionably contains the albite molecule to some extent as shown by the extinction angle on $b(010)$.

The dark-colored minerals are occasional small tablets of a greenish lepidomelane-like mica and prisms of a colorless augite of a wide extinction-angle. This latter is partly changed in some places to serpentine and in others into a fibrous green mineral that is believed to be hornblende. Occasional apatite and iron ore occur.

These lie in an excessively fine-grained ground-mass that appears to be composed of fine feldspar granules. It is so fine as to be almost cryptocrystalline, and even with very high powers little can be learned save that it appears holocrystalline, of untwinned feldspar, and is filled with fine ore grains and microlites of an extremely pale-green mineral occurring in slender needles, and which is thought to be pyroxene. This

dense ground-mass when treated with acid is found to yield a small quantity of gelatinous silica, and as no other mineral appears to be present which could yield it, it is probable that this comes from a small quantity of nephelite not otherwise to be detected.

This rock belongs then very plainly in the alkali syenite series, and is a porphyry with a somewhat trachytic habit. The contrast between the size of the feldspar phenocrysts in the main type and in the contact form indicates that they were formed in place and not brought up from below, which idea is favored by the vastly greater number of them in the contact type. This is analogous to the facts shown at Gray Butte and mentioned elsewhere in this paper.

The shaft of the mine has been sunk upon a mass of *shonkinite*, a dark, basic, micaceous rock which appears to form a dike cutting transversely across both the periphery of the trachyte intrusion and its marginal zone of hardened, baked sedimentary rocks. This rock is of a moderately coarse grain, and is filled with stringers and thin seams of pyrite. It consists of iron ore, apatite, augite, biotite, and soda orthoclase feldspar. It is moderately coarse-granular and the augite and biotite which are the chief ferro-magnesian minerals are enclosed poikilitically by the alkali feldspar in broad plates. The structure is hypidiomorphic and the rock is identical with a similar one from an intrusive center on Beaver Creek, and to avoid repetition further details are deferred to the more complete petrographic description of the type occurring at the latter locality.

Its association, however, with the syenite is a matter of great interest, and shows that it is here the complementary rock to that type. The complementary relation between syenite and shonkinite we have already shown on two occasions,* and the present example will be included in the second part of this paper, where we will present further cases in the Bearpaw Mountains with more complete description and a fuller discussion.

The gangue of the ore body is a brecciated and much altered trachyte or syenite-porphyry. The fragments composing it are angular, of varying size, color, and character, and the rock shows considerable pyrite scattered throughout its mass. Examined under the microscope, the thin section shows untwinned feldspar phenocrysts, biotite, and iron ore in a feldspathic ground-mass consisting apparently of singly or untwinned alkali feldspars. It is now so greatly altered by leaching solutions, filled with calcite which exists everywhere in thin films, and the feldspar is so changed into sericite, that it would not be safe to assert more than this about it.

* Bull. Geol. Soc. Am., vol. vi, p. 400, 1895; this Jour., vol. 50, p. 467, 1895.

ART. XXXV.—*Pleistocene Marine Shore-Lines on the South Side of the St. Lawrence Valley;* by ROBERT CHALMERS, of the Geological Survey of Canada.

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ALTHOUGH it has been known for many years that a considerable rise of the land took place in the St. Lawrence Valley in the later Pleistocene period, the facts on which this conclusion was based have been few and disconnected. Sir J. W. Dawson first showed that marine deposits of Pleistocene age, containing fossils, occur on Mount Royal, at Montreal, 470 feet above the sea.* Later, the same author found evidences of ancient shore-lines at the same place at a height of 550 feet;† and Adams and de Geer discovered beaches there also at an elevation of 600 feet and upwards. Along the lower St. Lawrence, between Sainte Flavie and Rivière du Loup, marine shore-lines were observed by the writer in 1885 at heights varying from 345 to 375 feet. During the seasons of 1894 and 1895, however, an opportunity was afforded me of examining the evidences of the Pleistocene upheaval along the south side of the St. Lawrence in much greater detail than has heretofore been done, and data have been obtained showing the extent of a differential uplift there with some approach to accuracy. The observations referred to, it may be stated, are in continuation and extension of those relating to changes of level made in New Brunswick, Nova Scotia, Prince Edward Island and the Gaspé peninsula, the results of which have appeared from time to time in the reports of the Geological Survey of Canada and are shown on the maps accompanying them.‡ In a report recently issued,§ the whole of the work relating to this subject in the eastern maritime provinces is summarized, and it will be seen that the highest Pleistocene marine shore-lines have been traced continuously along the coast from the International boundary between the State of Maine and New Brunswick northward to the mouth of the St. Lawrence River, also around Prince Edward Island and the Magdalen Islands. On the maps accompanying this report these shore-lines are laid down, and in the text their elevations are tabulated and the differential movements they indicate described. This investigation is now in progress along the south side of the

* The Post-Pliocene Geology of Canada, Can. Naturalist, vol. vi, 1872.

† The Canadian Ice Age, p. 63.

‡ Annual Report Geol. Survey Can., vol. ii, 1886, Part M; ibid., vol. iii, 1887, Part N; ibid., vol. iv, 1888–89, Part N, with accompanying maps.

§ Annual Report Geol. Survey Can., vol. vii, 1895, Part M, with accompanying maps.

St. Lawrence Valley, as stated, and will, if possible, be continued until the International boundary is again reached in the neighborhood of Lake Champlain. The following notes on the salient features of these high-level shore-lines, though incomplete, are offered meantime in the hope that they may be of interest to students of Pleistocene geology.

Topographic features of the region on the south side of the St. Lawrence River.—The border of the highlands or mountainous country called the Notre Dame Range, extending from the extremity of the Gaspé peninsula to the International boundary in the State of Vermont, runs close to the St. Lawrence as far west as Kamouraska. Thence it gradually recedes from the river as we proceed westward and near Lake Champlain is not less than forty or fifty miles distant from the St. Lawrence River. The elevation of these mountains is from 1,500 feet to 2,000 or 2,500 feet, the central range being of course the highest. Though intersected in a few places by rivers, as, for example, by the Ste. Anne des Monts, the Chaudière and St. Francis, the mountains, nevertheless, present a gradually ascending slope, rising from the marine plain of the St. Lawrence Valley, of almost unbroken continuity throughout their whole length. Along the foot of the range lower ridges extend parallel thereto, especially below Quebec, which, however, become more and more broken and of less altitude as we leave the higher grounds and approach the shore of the river. Above Quebec a considerable breadth of low-lying country intervenes between the mountains and the St. Lawrence, described below, in which few elevations occur.

The marine plain on the south side of the St. Lawrence Valley.—A large portion of the great marine plain of the St. Lawrence Valley lies on the south side of the St. Lawrence River, i. e. between it and the northern base of the Notre Dame Range (the low-lying country referred to above being a part of it). This part of the plain extends continuously along the whole valley, with hills and ridges, often isolated, rising here and there which relieve the monotony. Along the lower St. Lawrence it is comparatively narrow, in some places forming merely benches; but it widens as we ascend the valley. At Kamouraska it is from half a mile to two or three miles in width; at Montmagny from two to five miles; at Lévis it is not less than fifteen miles wide; at Ste. Henedine and the mouth of the Chaudière River the width is about twenty miles, and at Ste. Julie and Somerset stations, Grand Trunk Railway, twenty-five miles or upwards. Between South Somerset and the International boundary it is from forty to fifty miles in width. The deposits constituting the plain are Saxicava sand, Leda clay and bowlder-clay with some residuary material

beneath in places. The height of its surface above the sea varies from a few feet to five hundred feet or more; but the average height does not exceed two hundred and fifty to three hundred feet. As stated already, it is traversed by ridges, especially near the base of the Notre Dame Range, where the plain is usually highest. To the southeast of Ste. Julie and Somerset stations, Grand Trunk Railway, the border of the marine plain, at the foot of the mountains, was found to be about 600 feet in height. From this point it slopes away gently to the northeast, north and northwest, and it would seem as if the margin here must have received a somewhat greater differential uplift than other parts in the vicinity. A number of facts, which cannot be given in detail, lend support to the view that this local uplift, the axis of which is, perhaps, transverse to the general trend of the mountain range, i. e. approximately in a southeast and northwest direction, was of slightly greater extent here than to the eastward. But the forces producing the general Pleistocene upheaval seem also to have effected similar local deformations in other places in the region on the south side of the St. Lawrence River.

From the foregoing facts, therefore, it will be seen that the topographical and physical features of the region described are such as would be likely to favor the formation of terraces or beaches along the shore of the Pleistocene sea which occupied the St. Lawrence Valley.

Along the inner border of the marine plain the terraces and beaches representing the upper limit of the subsidence, and showing the extent of the subsequent upheaval, are to be found. In most places they consist of a series of two, three, or more, and are usually formed of stratified, water-worn materials with bowlder-clay beneath. Sometimes they retain their original outlines continuously for considerable distances; in other cases they are broken and denuded. The lower terraces are always best preserved. Occasionally we find a terrace or water-line cut into the bowlder-clay; but as a rule the beaches partake largely of the character of those formed along the coasts at the present day.

Highest Pleistocene Shore-lines.— Commencing with the beach at Gaspé Bay, we shall proceed westward along the south side of the St. Lawrence River. A considerable gap lies between Gaspé and Ste. Flavie, where I have not yet been able to make the necessary levellings. With this exception the observations form a connected series along the north side of the Notre Dame Range as far west as Somerset station, Grand Trunk Railway. From Somerset or Arthabaska westward to the International boundary the beaches have not yet been traced along the north side of the mountains.

The heights given are from aneroid readings based on the levels of railway stations, and are all referred to mean sea level. Those along the Chaudière valley are only approximate, the shore lines being some distance from railway stations; elsewhere they lie near railways, and the heights may, therefore, be assumed as accurate within a small limit of error:

1. At Gaspé Bay (Ann. Report Geol. Survey Can., vol. vii, p. 22 M)..... 225 to 230 feet.
2. Near Ste. Flavie station, Intercolonial Railway, three terraces or beaches, viz: at 246 to 250 feet, at 300 feet and at..... 340 to 345 "
3. At Rimouski, three beaches also, viz: one at 260 feet, another at 330 feet and a third at ..... 367 "
4. South of St. Simon station, I.C.R. ..... 345 and 375 "
5. In rear of Trois Pistoles station, I.C.R..... 345 and 375 "
6. South of Rivière du Loup station, I.C.R., along the Temiscouata Ry., two shore lines at ..... 350 and 420 "
7. Near St. Gervais, southeast of St. Charles Jct. I.C.R., two levels at.....510 ft. and 540 to 550 "
8. At St. Anselme Mountain, 15 miles southeast of Levis, several terraces, height .. 540 and 555 "
9. A wide terrace forming part of the marine plain occurs on the west side of the Etchemin River above St. Anselme station, Quebec Central Railway..... 575 "
10. Between Etchemin River and Ste. Henedine station, Q.C.R., west of No. 9 ..... 620 "
11. On road going southeastward from Ste. Henedine station, Q.C.R., to Ste. Marguerite village, half a mile from Ste. Henedine ..... 715 "
    Further up hill on south side of a valley .. 750 "
12. On the east side of the Chaudière valley at Ste. Marie ..... 740 to 750 "
13. On the west side of the Chaudière valley, opposite the same place..... 760 "
14. Westward near the head of Beaurivage River, on road from Ste. Marie to St. Sylvester ..... 835 "
15. On road from Ste. Julie station, Grand Trunk Railway, to Inverness, at northern base of mountains, terraces at 850, 865 and 895 "
16. On a road farther west leading from Ste. Julie or Somerset station, G.T.R., towards St. Joseph and Williams lakes, terraces also at northern base of mountains, at the following levels: 720 feet, 755 to 765 feet, well defined, and a third, which is somewhat denuded and abuts against an escarpment at..... 860 "
    Gravel hills and mounds here rise to 885 and 890 "

The shore-lines above described face the open St. Lawrence valley, either where it is now occupied by the sea, or has been occupied by it during the Pleistocene period.

No fossils have yet been detected in the terraces, though they have been found in a number of places in the marine plain of which the terraces or shore-lines form the margin. Very little search for fossils has, however, been made in them.

The Chaudière and St. Francis rivers intersect the mountain range, along the north side of which the shore-lines have been traced, by valleys as low as the marine plain along the St. Lawrence River. During the Pleistocene subsidence the sea invaded these valleys, and shore-lines are, therefore, found along the banks at the present day. Not only the main valleys of the Chaudière and St. Francis have been thus occupied by the sea, but a wide extent of country to the southeast of the mountains referred to was also overflowed (unless the relative levels were wholly different then from what they are now), and apparently formed estuaries in which thick deposits of stratified sand, gravel and clay were laid down.

Following the valley of the Chaudière southward from Ste. Marie we find shore-lines in numerous places—one of these on the west side opposite the village of St. Francois, being at a height of 870 to 875 feet. Another occurs seven or eight miles above the confluence of the Du Loup and Chaudière rivers. Here an extensive terrace spreads out in the valley of the latter river which I was informed extended across the country to the Du Loup valley. Prof. J. W. Spencer and I examined this terrace together. In the valley of the Chaudière it is 870 to 875 feet high; in the Du Loup valley near St. Come it is slightly higher, being 890 to 900 feet.

In the drainage basin of the St. Francis River, terraces were observed which seem to be related to the shore-lines on the northwest side of the intervening mountains and correspond with them in altitude. One of these stretches along the southeastern base of Dudswell Mountain for five or six miles, facing a great valley to the south, through which the St. Francis River flows. Its height is from 840 to 850 feet.

At the north end of Lake Memphremagog, and extending towards the base of Orford Mountain, terraces occur composed of gravel, sand and clay, resembling the Saxicava sand and Leda clay of the St. Lawrence Valley. Fossils have not yet been found in these deposits, but no thorough search has been made for them. The height of the terraces is from 860 to 865 feet. A valley of considerable width extends from the north end of Lake Memphremagog along the course of its outlet—the Magog River—by Little Magog Lake, thence to the main valley of the St. Francis River. Through this valley the sea

could easily have reached the basin of Lake Memphremagog during the later Pleistocene subsidence, if the relative levels then were not entirely different from what they are at the present day. Thick deposits of stratified sand, gravel and clay occur along this valley; but I have not had time yet to examine them for fossils. Many years ago fragments of shells were found in this valley near Little Magog Lake which were reported on by Dr. T. Sterry Hunt as follows: "It is worthy of record that on Lot 6, Range XIV, of Ascot, Mr. A. Michel detected shells in clay beds which were too imperfect to be preserved, but from a drawing made on the spot appear to be a species of *Mya*."*

Terraces and plains occupying higher levels than those described were observed along the Quebec Central Railway about the headwaters of St. Francis River, also on the divide between these and the Chaudière waters. Between Tring and Robertson stations one was seen at a height of about 1040 feet. At the west end of Lake Aylmer another occurs at about 1075 feet. These were at first supposed to be lacustrine, but there seem to be no barriers which could have held in lakes at these levels. The terrace at Lake Aylmer is apparently continuous with other terraces or plains surrounding several of the lakes in this vicinity. If these terraces are marine they indicate a greater differential uplift of this portion of the country—a theory which was broached on a previous page,—but in the absence of fossils and of detailed examination no positive conclusion can be reached concerning them.

In the valley of the Coaticooke River high-level terraces were also observed. These appear, however, to be bounded by the sides of the valley and enclosed in longitudinal basins, narrow at both ends, and sometimes end on to each other. The height of one at Coaticooke station, Grand Trunk Railway, is about 1210 feet, and of another at Norton Mills is not less than 1250 feet.

In regard to the highest marine shore-line along the north side of the Notre Dame Mountains, which has been traced from the Gulf of St. Lawrence as far west as South Somerset, Quebec, the question arises whether it is likely to continue further to the west at or near the height reached where we left it and merge into the Iroquois beach? The last mentioned beach has been traced along the south side of Lake Ontario by G. K. Gilbert from Lewiston, N. Y., where it is 385 feet high, eastward to Watertown, N. Y., where the height is 730 feet. Thence it was followed by J. W. Spencer, who contends that it is of marine origin, to Fine, where the height attained is

* Report of Progress, Geol. Survey Can., 1863–66, p. 87.

972 feet.* Prof. Spencer extended his levellings still farther to the east, along the northern base of the Adirondacks, finding what he regarded as beaches at different levels up to 1200 and 1350 feet. The evidence as to these was, however, disputed by Prof. Gilbert.†

Mr. F. B. Taylor, who has examined a number of the beaches in the region of the Great Lakes, regards the Iroquois as coinciding with other beaches to the west, and reports some evidence of marine shore-lines from the Lake Champlain basin. On this point he argues thus: "But if the sea filled the Hudson-Champlain trough, attaining a height of 700 feet or more at the north end of Lake Champlain, it is impossible to avoid the inference that this was the time of the formation of the Iroquois, Chippewa and Herman beaches."‡

Baron de Geer, while in America, found a marine shore-line in the Lake Champlain valley, at St. Albans, Vermont, 658 feet high.§

The distance between the levelled points of the marine shore-line of the St. Lawrence valley and of the east end of the Iroquois beach is still so great, however, that it seems scarcely permissible to draw any inferences as to their probable relation to each other based on the levels now at hand. But if the terraces at the north end of Lake Memphremagog are really marine, and have corresponding terraces on the northwest side of the intervening mountains at or near the same height, then the two high-level beaches referred to—the St. Lawrence and the Iroquois—would thus have their levelled points brought much nearer to each other, and may, indeed, prove to be one and the same beach. In that case, as the St. Lawrence beach is certainly marine, there would be no escape from the conclusion that the Iroquois beach is also marine. But further detailed examination and levelling are required to satisfactorily determine the question.

Ottawa, February 4th, 1896.

* This Journal, vol. xl, 1890, pp. 443–451. The heights of the Iroquois beach, etc., are referred to sea level, Lake Ontario being 247 feet high, according to the U. S. Lake Survey.

† Bulletin Geol. Soc. of America, vol. iii, pp. 488–495.

‡ This Journal, vol. xlix, 1895, pp. 249–270.

§ Proc. Boston Soc. of Natural History, vol. xxv, 1892, p. 469.

Art. XXXVI.—*An Occurrence of Free Gold in Granite;* by George P. Merrill.

The specimen described below was received at the National Museum at the close of the New Orleans Exposition (1884–85). It was labelled as simply "gold ore, Sonora, Mexico," and appeared on casual inspection to be an ordinary mica-granite with small disseminated particles of free gold scattered over the surface. It was seen at once to be something worthy of investigation, although at the time it was assumed to be doubtless a case of local impregnation of the rock forming the wall of a vein. The sample was laid aside and quite forgotten until the fall of 1895, when the writer's attention was once more called to it while preparing for the Atlanta Exposition a series of specimens illustrating the occurrence of gold and silver in nature. It has now been the subject of more careful study, with the results as given below:

As above noted, the rock * appears on casual inspection to be an ordinary black mica granite considerably weathered, somewhat brownish and quite friable. Quartz, feldspar and black mica are all conspicuous and easily determined, the feldspars occurring in crystals some 5–10^{mm} in diameter. The striking feature of the rock is, however, an abundant sprinkling of small flecks of native gold, not merely over the surface, but throughout the entire mass of the specimen, which measures some 125^{mm} × 80^{mm}, by 40^{mm} in greatest thickness.

Under a pocket lens these flecks are so abundant that in extreme cases a half dozen or more are comprised within a space of 10^{mm} square. They are very small, rarely exceeding a millimeter in diameter, and are disseminated throughout the rock, not only as interstitial flecks among the mica scales, but apparently enclosed in both the feldspar and quartz granules. To finally determine this point, a number of thin sections were prepared and submitted to microscopic examination, with results in every way confirmatory.

The rock is, as stated, apparently a normal black mica-granite, the feldspar having a pronounced microperthite structure, and being in most cases badly muddied through kaolinization. The mica has undergone a considerable amount of chloritic alteration. Quartz occurs in the customary interstitial granular forms; fluidal cavities are neither large nor abundant. Magnetite is a common accessory and more rarely apatite and sphene. No sulphides of any kind were detected. The gold occurs associated with the mica or again wholly imbedded in

* Specimen 64987 U. S. National Museum Collections.

the mass of the quartz granules and feldspars. In such cases it does not appear to have been deposited, as was at first thought probable, along fissures, as a secondary constituent, but is completely enclosed in the fresh and unfractured minerals in most beautifully perfect arborescent and extremely thin, platy forms as if deposited directly from solution. Careful search was made for indications of impregnation, by means of solutions, along preëxisting fractures or cleavage planes. But, while in some cases the metal does occur in thin platy forms in what are now fractures or minute rifts, there is nothing to indicate that these existed as such at the time the gold was deposited, but rather that they are due to the subsequent weathering of the rock. The plates do not lie in one common plane, but are scattered at haphazard at all angles with the orientation of the crystals in which they are imbedded. Moreover many of the forms are so branched, moss-like or arborescent, that it is impossible to consider them as formed in this manner. No pyrite or other sulphides or their decomposition products can be detected. There is apparently no way of accounting for the gold other than by considering it an original constituent of the rock, a product of cooling and crystallization from the original magma. This of course on the supposition that the rock is a true granite, which it in every way resembles.

This occurrence is of unusual interest, if not of importance. So far as the writer is aware, nothing quite comparable with it has been noted.

J. B. Jaquet has briefly described and figured * an occurrence of free gold in microcline, the rock in which the latter occurs consisting essentially of microcline and quartz, impregnated with hematite. He remarks that it somewhat resembles the coarsely crystalline granite found in the schists of the region. Adams and Dawson have described † the ore of the Treadwell mine, Alaska, as a hornblende granite, "much crushed, altered, and impregnated with secondary quartz, calcite and pyrite," the last named carrying the gold, a considerable portion of which is free. In the present instance, however, the granite is altered only by the ordinary processes of superficial weathering, and as above noted contains no pyrite or other sulphides. The occurrence of the gold completely imbedded in the clear glassy quartz and unfissured feldspars apparently precludes the possibility of a secondary origin. The beautiful, highly lustrous yellow metal stands out in the sections, clear and distinct, whether in quartz or feldspar,

* Geol. of the Broken Hill Lode, etc., Mem. Geological Survey of N. S. Wales, Australia, No. 5, 1894.

† Am. Geologist, Aug. 1889.

without a trace of iron staining and with no cavities left by pyritiferous decomposition (see figs. 1 and 2).

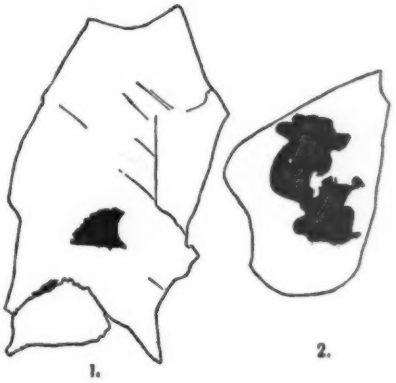

FIG. 1.—Free gold in feldspar.
FIG. 2.—Free gold in quartz. Gold indicated in black.

The Museum has no record as to the occurrence of this ore. But if, as is apparent, it is a normal granite, the occurrence is of importance in its bearing upon the question of the origin of the gold in veins and other secondary deposits.

National Museum, Mar. 2, 1896.

SUPPLEMENTARY NOTE.—Since the above was in type the writer's attention has been called by Mr. W. Lindgren to an article by W. Möricke (Tschermak's Min. u. Petr. Mittheil. iii, 1891) on Chilean ore deposits, in which free gold is described as occurring in a quartz-trachyte. The metal is visible with the aid of the microscope and is found both in glassy (pechstein) and crystalline varieties. It is regarded by Möricke as an original constituent.

Art. XXXVII—*A Theory of the "X-Rays;"* by Albert A. Michelson.

The principal facts, which any satisfactory theory of the "X-rays" is called upon to explain, may be summarized as follows:

1. The production of the rays by electric impulse, at the cathode,* in a highly exhausted enclosure.

2. Propagation in straight lines and absence of interference, reflection, refraction and polarization.

3. The importance of density of the medium as the determining factor in the transmission of the rays.

4. The production of fluorescence and actinic effects, and the action on electrified conductors.

Two theories have been proposed to account for these remarkable phenomena: (1) the theory of longitudinal waves; (2) the theory of projected particles.

In reference to the first theory it may be said that unless it is proved that an oscillatory discharge is essential to the production of the X-rays, there can be no reason for supposing that these rays are of a periodic nature—that they are wave-motion as commonly understood. The absence of interference, reflection and refraction is also a very formidable difficulty. Attempts have been made to account for the absence of these invariable accompaniments of every known form of wave-motion, but, as I think, with very indifferent success.

The most serious difficulty in the second theory is the attempt to explain the passage of the electrified particles of the residual gas (or of the electrode) through the walls of the vacuum tube. The query at once arises, if glass is permeable to these particles in virtue of their relatively great velocity, why is it not permeable (in lesser degree) to the same particles moving with smaller velocities? That it is not, is evident from the fact that vacuum tubes retain their high degree of exhaustion unimpaired for years.

In view of these difficulties, I would propose a third theory, which may be called the "ether-vortex" theory.

Let it be supposed that the X-rays are vortices of an intermolecular medium (provisionally, the ether†). These vortices

* Even should further experiment prove that the X-rays proper originate at the first obstruction encountered by the discharge, the fact remains that this discharge originates at the cathode.

† A possible objection occurs to the formation of ether-vortices in a medium which is usually considered free from viscosity; but the fact that vibrating molecules can and do communicate their motions to the surrounding ether shows that the communication of vortex motion may also be possible.

Though not a necessary part of the theory, it may be considered that the expulsion of the ether-vortices is due to an accumulation of ether in the cathode,

are produced at the surface of the cathode, by the negative charge, which forces them out from among the molecules of the cathode.

Let us now apply the tests above mentioned.

According to this theory, an oscillatory discharge, while it may be just as effective as a series of separate impulses, is not essential to the formation of the vortices. The vortices being forced outward from the surface of the cathode by the negative charge, the effect of the positive charge at the anode would be to drive them in. Hence their appearance at the cathode alone.

One of the greatest puzzles connected with the behavior of the X-rays is the fact that while they can pass almost unimpeded through air at atmospheric pressure (let alone water, glass, wood, flesh, bone, and metals) *when once outside the enclosure in which they are produced*, they cannot even reach the walls of the enclosure, except there be a very high vacuum within. This problem receives a very natural solution if it be considered that, in order that ether-vortices may result from the electrical impulse, this impulse must be communicated to them; and must not be dissipated in the interchange of molecular charges which accompanies, or rather produces, the discharge at moderate or high pressures.

As exhaustion proceeds there are fewer molecules present to effect this discharge with sufficient rapidity, and as this limit is approached there will be a division of the energy of the electric impulse between the electrified molecules and the ether-vortices, and in the end all the energy of the discharge will be confined to the latter.

The reason for the non-appearance of the rays under ordinary conditions is not that the rays cannot reach the walls of the enclosure or pass through them, but that they cannot form at all. The propagation of vortices in straight lines, the absence of interference phenomena, of reflection, refraction and polarization, follow from the properties of vortices, and from the absence of anything corresponding to a wave-front. The passage of an ether-vortex through a mass of matter may be compared with a passage of a smoke-ring through a wire gauze screen or a series of such; and as the motion of the rings is more impeded the greater the diameter and the number of wires per unit volume, so, the greater the number and the size of the molecules—that is, the greater the density—the more effective will the medium be in dissipating the energy of the ether vortices.

and this would lend support to the theory that this accumulation is not merely a result of the negative charge, but that this excess of ether is what constitutes the negative charge.

The production of fluorescence, actinic effects, and the dissipation of electric charges by light (which is an ether motion) would make it at least probable that similar (though perhaps not identical) effects would be produced by the motions of ether-vortices.

Professor J. J. Thomson has measured the velocity of cathode-rays and obtained a result so very far less than the velocity of light as to preclude entirely the idea of there being any connection between the two. If these results can be made to apply to the X-rays, the analogy with the properties of smoke-rings would lead us to expect such a result. The cathode rays have been shown by Lenard to have a considerable range in their properties, depending on the mode of their origin.* It seems likely that their velocities are to a considerable extent dependent on the potential and the suddenness of the electrical impulse; and if this were shown to be true of the X-rays, it would be to that extent a confirmation of the theory.

The foregoing evidence may be considered scarcely sufficient to entitle the proposition here advocated to the dignity of a theory, but it may at least merit consideration as a working hypothesis which may serve as a guide in future experiment.

* The distinction between the X-rays and the cathode rays appears to be somewhat artificial, and it seems probable that the X-rays are only cathode rays sifted by the various media they have traversed.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On some physical properties of argon and helium.*—Lord Rayleigh has made a new determination of the specific gravity of argon, using a large volume of the gas separated from atmospheric nitrogen by sparking with oxygen. The result obtained, referred to O_2 as 16, was 19·940. Professor Ramsay had previously obtained a density of 19·941 for the gas obtained by the magnesium method, so that it is evident that the products obtained by the two methods are identical. The author has also determined the refractivity of argon and helium, with the results that the refractivity of argon is 0·961, while that of helium is 0·146, compared with air as unity. The result in the case of argon is very unfavorable to the view that this gas is an allotropic form of nitrogen. The refractivity of helium is remarkably low, the lowest previously known being that of hydrogen, which is nearly 0·5 that of air. The results of determinations of viscosity were for helium 0·96 and for argon 1·21, referred to dry air. The latter number is somewhat higher than that for oxygen, which has stood at the head of the list of the principal gases in this respect. The author has found by spectroscopic examination that the gas emanating from the Bath springs contains both argon and helium, with probably less than 10 per cent. of the latter in the mixture of the two. Gas from the Buxton springs was found to contain about 2 per cent. of argon, while the presence of helium in this gas in very small quantity was probable, but not certain. The interesting question concerning the existence of helium in the atmosphere was attacked by allowing the greater part of samples of atmospheric argon to be absorbed by water and examining the residues by the spectroscope. It was expected that helium, since its solubility in water is but about one-fifth that of argon, would be concentrated in these residues if it were present. No helium could be detected in this way, and the author concludes that if helium be present in the atmosphere, it must be in very small quantity, probably much less than a ten-thousandth part.—*Chem. News*, lxxiii, 75. H. L. W.

2. *Mixed double halides of platinum and potassium.*—An investigation of the compounds represented by the formula $K_2Pt(Cl, Br)_6$, where chlorine and bromine exist in varying proportions, has been made by Herty. He found that the products prepared under varying conditions gave no definite relation between the chlorine and bromine, and that none of these substances remained constant in composition after recrystallization. The author therefore arrives at the conclusion that the products are simply isomorphous mixtures of K_2PtCl_6 and K_2PtBr_6. The previous contrary conclusion of Pitkin and of Pigeon may be considered as unfounded in the light of Herty's careful and elaborate work.—*Jour. Am. Chem. Soc.*, xviii, 142. H. L. W.

3. *The relative atomic weights of oxygen and hydrogen.*—A new determination of this important ratio has been made by JULIUS THOMSEN. The novel feature of his method consisted in evolving hydrogen, by means of strong potash and metallic aluminium, from a weighed apparatus and determining the amount of the element used from the decrease in weight of the apparatus. The result arrived at from a series of experiments was

$$H : O = 1 : 15{\cdot}8690 \pm 0{\cdot}0022.$$

This result agrees with remarkable closeness with the results of a number of other investigators, as will be seen from the following list cited by Thomsen:

Cooke and Richards	1 : 15·869
Rayleigh and Scott	1 : 15·862
Morley	1 : 15·879
Noyes	1 : 15·886
Dittmar and Henderson	1 : 15·867
Leduc	1 : 15·881

The author believes that the ratio is now definitely settled within very close limits, and there is no doubt that most chemists will accept a ratio very close to this, especially in view of the very elaborate work of Morley.—*Zeitschr. anorg. Chem.*, xi, 14.

H. L. W.

4. *The synthesis of caffeine.*—The complete synthesis of this important alkaloid, the active principle of tea and coffee, has now been made possible by the work of EMIL FISCHER and LORENZ ACH. The important step accomplished by the authors is the conversion of γ-dimethyl uric acid, by the action of phosphorus pentachloride, into chlortheophylline. The latter, by reduction to theophylline and subsequent methylation, gives caffeine. The γ-dimethyl uric acid has been produced, in a roundabout way only, from dimethyl urea as a starting-point, and the authors therefore consider the synthesis of no practical value at present on account of the expense. They believe that their results would have a practical importance if it were possible to methyllate uric acid directly so as to place two methyl groups in the alloxan nucleus. It is their opinion that as soon as the base becomes a cheap material through artificial preparation, it may have use in the manufacture of substitutes for tea and coffee to give them the same physiological action as the natural materials. —*Berichte*, xxviii, 3135.

H. L. W.

5. *Free hydrazine.*—Curtius, who discovered and investigated hydrazine, obtained the hydrate, $N_2H_4 . H_2O$, but did not succeed in isolating the anhydrous substance. LOBRY DE BRUYN has now obtained the free base by two methods. The first method consists in treating the hydrochloride with sodium methylate, when the following reaction takes place:

$$N_2H_4 . HCl + NaOCH_3 = N_2H_4 + NaCl + HOCH_3.$$

According to the second method hydrazine hydrate is heated with barium oxide at 100° and the product is distilled under diminished pressure. Free hydrazine is a liquid which boils at 113·5° (at 761^{mm}). By cooling below 0° it solidifies, and it melts at +1·4°. Its specific gravity is about the same as that of the hydrate, 1·003 (23°). It is a very stable body and can be heated above 300° without decomposition. The halogens act upon it with great violence, and it acts upon solid sulphur at ordinary temperature with the formation of hydrogen sulphide. Oxygen attacks the base, with the liberation of nitrogen, when it is exposed to the air. The author has also made the useful observation that hydrazine hydrate can be distilled under diminished pressure from glass vessels, since under 50° it does not attack glass. Curtius, operating under atmospheric pressure, was obliged to use a special apparatus of silver for the distillation.—*Bericlte*, xxviii, 3085. H. L. W.

6. *Practical Inorganic Chemistry*, by G. S. TURPIN, 12mo, pp. 158, London and New York, 1895. (Macmillan & Co. Price 60 cents.)—This is a course of laboratory work for beginners in chemistry. The experiments are very simple in character, and are such as can be carried out by very youthful pupils with limited facilities. Many of the operations are of a rough quantitative nature, designed as illustrations of chemical and physical laws. While the processes are clearly described, the results, in most cases, are not mentioned, so that the student is obliged to observe them for himself. A chapter is devoted to a very simple course in qualitative analysis, covering a range of seven metals and four acids. H. L. W.

7. *Chemical Experiments, General and Analytical;* by R. P. WILLIAMS, 12mo, pp. 110, Boston, 1895 (Ginn & Company).—This book is intended for a somewhat comprehensive course of laboratory work in high schools, academies and colleges. The subject matter is condensed, abbreviated and tabulated to a large degree. It seems that more help should have been given to the student in the way of explanations. Upon the mere mention of such words molecule, affinity, stochiometry, definite proportion and the like, the pupil is expected to study these subjects "outside the laboratory," and he is expected to write chemical equations, although none are given in the book, even in some instances where the products of the reactions are not mentioned. Unfortunately the book contains a number of astonishing inaccuracies. H. L. W.

8. *A Text Book of Gas Manufacture for Students;* by JOHN HORNBY. 12 mo., pp. 261, London, 1896 (George Bell and Sons). —This little book gives an excellent account of the subject in view. The chemical and mechanical features of the processes are clearly described and the illustrations are numerous and well-chosen. H. L. W.

9. *Methods of determination of Dielectric Constants.*—W. NERNST refers to his method of measuring the dielectric constant of insulators and bad conductors (Zeitschr. f. Phys. Chem. xiv,

p. 622, 1894) and illustrates its accuracy in comparison with previous electrometer methods and with the glass trough method. Under his direction J. F. SMALE has employed two electrometers of the form designed by Bjerknes, in which a needle is acted on inductively by two quadrants, which are connected to the terminals of a Ruhmkorf coil. The needle and the quadrant are immersed in the dielectrics which are to be compared. It is pointed out that the needle of the electrometer must be placed in a comparatively large mass of the dielectric, which must also fully surround the electrodes or quadrants. J. F. Smale describes an ingenious gas regulator to obtain uniform revolution of the armature of a little alternating machine which excited the transformer which was connected with the electrometers, which in turn were connected in parallel. Smale found a satisfactory agreement between the electrometric method and the bridge method employed by Nernst.—*Ann. der Physik und Chemie* No. 2, 1896, pp. 209–222. J. T.

10. *Dielectric Resistance.*—P. DRUDE elaborates the conception of dielectric resistance to lines of electrostatic force, analogous to the conception of magnetic resistance previously touched upon in his treatise "Physik des Aethers"; and also by Professor Nipher, of Washington University, St. Louis.—*Ann. der Physik und Chemie* No. 2, 1896, pp. 223–231. J. T.

11. *Index of refraction and reflective power of water and alcohol for Electric Waves.*—If the wave length of electric waves along two parallel wires is measured, first with air between such wires and afterwards when a portion of the space between them is filled with a dielectric, the ratio of the resulting wave lengths will give the index of refraction of the dielectric for the electric waves. A. D. COLE, working in this manner, has obtained 8·95 for the index of refraction of water at 19° C. and 5·2 for alcohol at 18° C. With the employment of mirrors to reflect the electric waves from the surfaces of water and alcohol, it was found that waves 5^{cm} long gave with reference to Fresnel's formula, both for rays polarized perpendicular to the plane of incidence and also parallel to it, the same value for the index of refraction (calculated from observed reflective power). For water $n=8{\cdot}8$ and for alcohol $n=3{\cdot}2$. With alcohol the index of refraction was much greater for long electric waves than for short.—*Ann. der Physik und Chemie* No. 2, 1896, pp. 290–310. J. T.

12. *Röntgen Rays.*—Righi, in a preliminary paper (Rendiconto delle Sessioni della R. Accademia delle Scienze di Bologna, Feb. 9, 1896), states that the Röntgen rays have the property of dispelling positive charges of electricity as well as negative. Professor J. J. THOMSON has independently made the same observation. (Nature, Feb. 27, 1896.) Professor Thomson also states that when the Röntgen rays pass through any substance they make it for the time a conductor of electricity. This explains the fact that an electrified plate in air loses its charges whether it be electrified positively or negatively. The air is converted into a

conductor and the charge escapes through it. The leakage through non-conductors is due to a kind of electrolysis, the molecules being split up by the rays. Professor Thomson thinks that the rays are not all of the same kind. Crookes tubes generally improve for a time after they are sealed off from the air pump and then begin to deteriorate. Mr. A. A. C. SWINTON describes a simple apparatus for determining whether a Crookes-tube is efficient. It consists of an opaque pasteboard box with a simple aperture at one end to which the eye is applied. The other end is provided with an opaque diaphragm of double black paper, upon the inner side of which is laid a piece of blotting paper impregnated with platino-cyanide of barium in a crystalline state. Shadows of objects held against the diaphragm are clearly seen. Mr. Swinton has thus seen the bones in the thick portion of his hand. This apparatus is similar to that described by Professor Salvioni of Perugia.—*Nature*, Feb. 27, 1896. J. T.

13. *Experiments with the Röntgen rays.*—DOELTER has recently called attention to the fact that the X-rays of Röntgen may be used as a means of distinguishing between different gems, as also between them and their imitations. A true diamond may thus be readily told from a false one. While rock crystal, topaz, strass and spinel are opaque to the rays, the varieties of corundum (ruby, sapphire) transmit them to some extent. The usually accepted relation between the opacity of the substance to the X-rays and its density finds some exceptions, according to Doelter, among minerals. He finds sulphur (G. = 2) and realgar (G. = 3·4), quartz (G. = 2·6), fluorite (G. = 3·1), quite opaque; corundum (G. = 4·1), as stated above, transmits the rays somewhat, while diamond (G. = 3·5) and graphite (G. = 2) transmit much better. Most silicates are opaque; this is true of mica in layers of 1^{mm} in thickness. In sections of $\frac{1}{4}^{mm}$ it is possible to distinguish between the transmissive powers of amphibole, garnet, quartz, mica, feldspar.—*Private publication*, Gratz, Feb., 1896.

14. *The Elements of Physics; A College Text-book*, by E. L. NICHOLS and W. S. FRANKLIN, vol. i., 228 pp., 8vo. New York, 1896 (Macmillan & Co.).—This volume forms the first of a series of three in which the authors propose to develop the fundamental principle of Physics; it embraces the subjects of Mechanics and Heat, while the other two volumes are to be devoted to Electricity and Magnetism, and Sound and Light respectively. The scope of the work and the method of treatment differ from those of many existing text-books inasmuch as the authors write for a somewhat more advanced grade of students than those which form the mass of many college classes. It has thus been possible for them to assume a knowledge of the Calculus and in general to treat the topics more concisely and from the mathematical side; long descriptions of the applications of the principles are thus avoided. For those students for whom the work is prepared, who desire to make a serious study of Physics, this excellent new text-book cannot fail to be of much value.

II. Geology and Natural History.

1. *Contributions to the Cretaceous Paleontology of the Pacific Coast: The Fauna of the Knoxville Beds;* by T. W. Stanton. (Bulletin U. S. Geological Survey, No. 133.) 132 pp., 20 plates, Washington, 1895 [issued Feb. 3, 1896]. Abstract by the author. —The Knoxville beds as described in this paper form the lowest division of the Lower Cretaceous section in California, and are found in the Coast ranges from San Luis Obispo County, Cal., (near latitude 35°) on the south to the neighborhood of Seattle, Washington, on the north, though they are not continuously exposed throughout that distance. The name was first applied in 1885 by Messrs. White and Becker to the Aucella-bearing portion of the ill-defined Shasta group. Since then the beds have been studied more in detail, especially by Mr. J. S. Diller, and a résumé of his stratigraphic results is given together with the author's observations made during portions of two field seasons spent in the most important areas.

Lithologically the beds consist of a series of dark clay shales alternating with sandstones, usually in thin beds, with local deposits of heavy conglomerate and more rarely small limestone masses. The thickness is very great, always several thousand feet and, according to one of Mr. Diller's measured sections, reaching a maximum of nearly 20,000 feet in Tehama County, Cal., where the series is best developed both faunally and lithologically.

The underlying formations have not been very definitely determined owing to the fact that they are usually unfossiliferous and frequently more or less obscured by metamorphism and by the intrusion of igneous rocks. The evidence tends to prove that the Knoxville rests on rocks varying in age from Carboniferous to probably Upper Jurassic. The Horsetown beds which rest conformably on the Knoxville are, in part at least, referable to the Gault.

The invertebrate fauna as now known consists of 77 species and varieties, of which 50 species and one genus (Cardiniopsis) are described as new. Most of these are rare, having been found at only one or two localities, but the several forms of Aucella are very abundant, often filling the rocks and occurring at many horizons. All but 7 of the species are Mollusca, including 33 species of Pelecypoda, 1 of Scaphopoda, 18 of Gastropoda, and 18 of Cephalopoda, of which 15 are Ammonoids and 3 are Belemnites. The ammonites belong to the genera Phylloceras, Lytoceras, Desmoceras, Olcostephanus and Hoplites, the last being especially well represented. The other seven species include 5 Brachiopoda and two Echinodermata.

As a result of the study of the fauna the Knoxville beds are referred to the Lower Cretaceous and are regarded as later than the Mariposa beds of the Sierra Nevada, which are also Aucella-bearing but of Jurassic age.

Beds of Knoxville age and with a similar fauna occur in British Columbia and probably in Alaska and Mexico. Correlation may also be made with an indefinite upper portion of the Aucella-bearing series in Russia, especially with the "Petschorian."

It is a peculiar fact that this fauna has nothing in common with the fauna of the Texan Comanche series, which must have been in part contemporaneous. Not only are the species distinct but even most of the genera are different, and yet the eastern sea with its Comanche fauna at one time extended as far west as Arivechi in Sonora, while the Mexican Aucella beds, which faunally seem to belong to the Pacific basin and in part comparable with the Knoxville, are much farther east in San Luis Potosi. These facts have an important bearing on the history of the continent, but their exact interpretation must await more detailed stratigraphic and faunal studies in Central Mexico.

2. *Contribution a l'étude des lapiés.*—In a paper in "*Globe, journal geographique*," Tom. xxxv, Genève, 1895, entitled *La topographie du désert de Platé* (*Haute-Savoie*), M. EMILE CHAIX has given a detailed description of the peculiar phenomena called "*Karrenfelder*" by Heim, Fr. Becker and others, and "*lapiés*" by Charpentier, Rollier, Duparc and LeRoyer, etc. Lapiés are barren rock surfaces, high up in the Alpine glacial regions, smoothed off in general, but crossed by shallow channels or grooves commonly in the direction of the slopes; with deeper crevasses, continued for long distances in a more or less straight line and transverse to the slopes, though sometimes crossed by others at nearly right angles and in line with the slopes of the rocks. The author has mapped with great care the direction and position of the crevasses of the Désert de Platé, and has figured typical examples of the peculiar structure in 16 photogravure plates.

After describing them in detail, and referring to the various theories offered by other geologists in their explanation, he adopts the view that the more superficial grooves and channels (*ciselures* and *rigoles*) are the result of chemical erosion; and that the deeper *crevasses* are the result of torsion, as suggested by the investigations by Duparc and LeRoyer. He concludes that these two classes of phenomena, in the case of the Désert de Platé, were produced at different times, the latter being of ancient and the former of post-glacial origin, the edges of both having been more or less rounded by later atmospheric and aqueous agencies. H. S. W.

3. *The geographical distribution of marine animals.*—In line with Walther's "Bionomie des Meeres," Dr. Arnold E. Ortmann* has contributed some interesting chapters to this rapidly crystallizing department of science, the geographical and geological

*Grundzüge der Marinen Tiergeographie. Anleitung zur Untersuchung der geographischen Verbreitung mariner Tiere, mit besonderer Berücksichtigung der Dekapodenkrebse von Dr. Arnold E. Ortmann (Princeton, N. J.), pp. 1–96, 1 chart. Jena (Gustav Fischer), 1896.

biology. Two or three points may be briefly referred to, which might be much enlarged on if our space would admit. In discussing marine regions of distribution the author reaches this significant conclusion, that the passage from the temperate to the polar climatic zones does not constitute so important a climatic boundary for the distribution of organisms as the passage from tropical to temperate. The most important climatic boundary is the line where the sum of the general fluctuations of temperature is so great that tropical organisms accustomed to an equable warm climate are unable to endure the changes; a greater reduction of mean temperature is found farther poleward, this being associated with the diminution of the amplitude of the fluctuation and is not to be regarded as a climatic limit of first rank.

In the chapter on the distribution of Decapods the conclusion is reached that the ancestors of Decapods, as well as Euphausiacea, were Nekton (open sea) animals, and as they were dependent upon the substratum they could exist only under littoral and abyssal conditions.

In an interesting chapter on the favoring and hindering means of distribution, the author emphasizes the importance of isolation, and formulates the four following as the chief factors in the formation of new species, viz: 1, Adaptation to external conditions forms variations; 2, the transmission of adaptations fixes the variations, thus occasioning groups of morphologically similar forms; 3, natural selection modifies these morphological groups causing mutation in definite directions; 4, isolation of the morphological groups produces differentiation and direction of mutation and thus the production of separate species. We hope to have, in a future number, a fuller discussion by the author of some of these points. H. S. W.

4. *Charles Lyell and modern Geology;* by Prof. T. G. Bonney. pp. 224, New York (Macmillan & Co.), 1895.—This is a brief but readable account of the life of a geologist whom all the world knows, but whose memory will be revived for the younger generation by this compilation. It is one of the Century Science Series edited by Sir Henry Roscoe, and like others of the series the brevity of the work is likely to lead earnest students to look up the original biographies of these scientific worthies who have made the present century famous.

5. *Beiträge zur Geophysik. Zeitschrift für Physikalische Erdkunde.* Herausgegeben von Prof. Dr. Georg Gerland. II Band. 2–4 Heft. pp. 197–773, Stuttgart, 1895.—This part closes the second volume of the valuable *Beiträge zur Geophysik*, edited by Professor Gerland, the first volume of which was noticed in volume xxxv (p. 344) of this Journal. Some of the papers here included are: A. Schmidt, Erdmagnetismus und Erdgestalt; E. v. Rebeur-Paschwitz, Horizontalpendel-Beobachtungen auf der Kaiserlichen Universitäts-Sternwarte zu Strassburg; E. Rudolph, Ueber submarine Erdbeben und Eruptionen; H. Wagner, Areal und mittlere Erhebung der Landflächen sowie Erdkruste.

6. *Structure-Planes of Corundum and some Massive Minerals (simple rocks) from India and Australia;* by J. W. JUDD (Min. Mag., vol. xi, No. 50).—The author, as the result of his studies, states that "corundum has at least three sets of structure-planes but that none of these can be regarded as true *cleavage*. Two of these structure-planes, those parallel to the base 0R(111) and to the prism ∞P2(10$\bar{1}$) are normal solution-planes; the third set of structure-planes, those parallel to the unit rhombohedron R(100), are gliding planes which when developed become secondary solution-planes." He also says that the partings observed "appear to be due . . . . . to chemical alterations taking place along these structure-planes of the crystal."

In the second portion of the paper an account is given of some minerals which occur on so large a scale as to form veritable rock masses. Some of these are occurrences of corundum at several localities in India; also rock masses made up of quite pure tourmaline of a black color and in fibrous form. A rock composed entirely of a green garnet is mentioned as occurring in dike form cutting serpentine; associated is another dike composed of nearly pure picotite (chrome spinel). L. V. P.

7. *Remarkable phosphorescence in Wollastonite;* by W. F. HILLEBRAND. (Communicated.)—In examining a fibrous mineral recently received from New Hartford, Oneida County, N. Y., which proved to be wollastonite, although of somewhat greater hardness (about 5·5) than the limit given in text-books, a most beautiful greenish-yellow phosphorescence was observed. The color is not very conspicuous by daylight, but in a dark room the phenomenon is very strikingly shown when fragments are heated below redness, or when the somewhat coarsely powdered mineral is thrown into a hot, but not red-hot, crucible.

Professor Penfield, to whom the specimen was sent, finds that "the columnar and compact varieties from Bonaparte's Lake, Lewis Co., N. Y., New Windsor, Orange Co., N. Y., and Bucks Co., Pa., show exactly the same phenomenon. Fragments of crystals from Diana, Lewis Co., N. Y., and Dognaczka, Banat, show only a slight phosphorescence, while a few of the crystallized varieties that were tested do not show it at all. The compact edelforsite of Hisinger, which Forchhammer (Danske Videnskab. Selskabs Förhandlingar, 1867, p. 64) by means of chemical analysis has shown to be impure wollastonite, exhibits the phosphorescence beautifully."

I may add that my own tests on material in the U. S. National Museum show that different specimens from the same locality may glow with very different intensities, as those from Natural Bridge, Lewis Co., N. Y., for instance. Several Bucks Co., Pa., specimens failed to phosphoresce, at least visibly, in daylight. The beauty of the phenomenon and its novelty as regards this species seem to merit publicity.

Washington, U. S. Geological Survey.

8. *Propagation of the sugar-cane.*—Director J. H. WAKKER, of the experiment station for the study of sugar-cane, in East Java, has published an important communication relative to this matter, which is likely to stimulate further investigation in all cane-producing districts. It is well known that in practice cane is universally propagated from cuttings or their equivalents, and, furthermore, this mode of perpetuation has very naturally resulted in a loss of the power to produce good seeds. Wakker, by prosecuting extensive and exact researches, has found that the power of producing viable seeds is not wholly lost by this plant, but is capable of at least partial restoration by proper selection. Close inspection shows that although a great majority of all the flowers of the cultivated varieties of the cane are practically sterile, it is possible in some instances to find a few scattering blossoms which can be utilized for artificial pollination. At the experiment station in East Java there are between two and three hundred varieties of Saccharum under cultivation, but of these only a very few (in fact only one to any great extent) are employed in Javan agriculture. The principal variety, the so-called "Cheribon-cane," does not seed at all, and the same is true of some of the others, but diligent search was rewarded by the discovery that in some good varieties efficient pollen could be obtained, and in some others there were receptive stigmas. The pollination in an illustrative case, namely, that in which Cheribon-cane was used for the female plant, was guarded from foreign influence by the use of a paper covering around the inflorescence. In the year 1893, Wakker obtained from these crosses 669 seedlings of remarkable vigor. From all of his experiments in that year, he procured 490 which had to be subsequently rejected, but he retained 179 of high promise. Most of these possessed a higher percentage of sugar than the parent plants, and were free from disease.

It is difficult to overestimate the value of these researches. The range of bud-variation in the cane is very wide, but it has seemed to tropical cultivators an almost hopeless task to lead the product of sugar up to a much higher percentage than at present by means of selection among these varieties, whereas it has been felt that if seeds could in any way be had, the initiation of new and more productive variations might reasonably be hoped for. It is understood that no appreciable advance in the process of sugar extraction is to be expected: on the other hand, a path for the successful cultivation of new varieties is now fairly broken and may speedily give us far greater production per acre than has hitherto been thought possible. G. L. G.

9. *Systematic arrangement of Australian Fungi, together with Host-Index and List of Works on the subject;* by D. MCALPINE, pp. 236, 4to (Melbourne, 1895).—The rapid development of the study of fungi in Australia is strikingly shown in the present volume by Prof. McAlpine, the government vegetable pathologist of Victoria, issued by the Department of Agriculture. Of the

311 titles given in the List nearly two-thirds are of works which have appeared in the last ten years; the greater part in fact in the last five years. Furthermore, while the works published prior to 1885 were almost entirely by a small number of British and continental mycologists, since that date the authors have been for the greater part persons living in Australia. The two hundred pages devoted to a list species of Australian fungi with habitats and notes of general characters, are followed by a list of 84 edible species. Excluding a few characteristic forms like *Cytturia Gunnii* and *Polyporus mylittæ* or native bread, one is struck with the fact that the edible species of Australia are nearly identical with those of Europe and North America. Some interesting statistics are given which show the whole number of fungi known in Australia to be 2,284, of which the greater number, 1,266, are Hymenomycetes. Uredincœ have 90, Ustilagineæ 39 and Myxomycetes 52 species. Of the different host-plants, the species of Eucalyptus are attacked by 54 species of fungi. The species of Acacia come next with 16 parasites. The Host-Index gives an alphabetical list of hosts with their parasites, without synonymy, and a note of the organs attacked. This work by Prof. McAlpine will be of very great assistance not only to Australian mycologists but also to those of other countries, who will be able at a glance to get a practical knowledge of the distribution of Australian vegetable parasites with a facility which would otherwise be impossible. W. G. F.

10. *Der Reis-Brand und der Setaria-Brand;* by Oscar Brefeld, Botanisches Centralblatt, lxv, 97–108, January, 1895.—In the twelfth part of his "Untersuchungen" Brefeld made mention of a smut of Oryza in which the spores did not germinate like those of other Ustilagineæ but produced a mycelial thread with spores arranged acropetally. He also described a very similar fungus on *Setaria Crus Ardeæ* from South America. Since then, having obtained abundant material of the latter fungus, he has been able to trace its development and finds that, besides the so-called smut-spores, the fungus produces a well-marked sclerotium. The sclerotia, after remaining for six months in moist sand, developed into stalked fruit-bodies much like those of *Claviceps purpurea*, the common ergot. The ascospores on germinating produced conidia like those produced by the smut-spores. Brefeld regards the sclerotium, ascoporic form and smut-spores as stages of the same fungus which he calls *Ustilaginoidea Setariæ*, and the smut of Oryza, although its development has not been traced, he places in the same genus on grounds of analogy. The genus Ustilaginoidea belongs to the Hypocreaceæ and the so-called smut-spores in this case correspond to the chlamydospores of species like *Hypomyces chrysospermus*. Brefeld ventures to predict from this case that other supposed species of Ustilagineæ will eventually be proved to be stages of Ascomycetes. It may be said, on the other hand, however, that, in his Untersuchungen, Brefeld showed that, although the Oryza-smut had been originally placed

in the Ustilagineæ, the development of the spores were in an important respect different from those of other Ustilagineæ. This being the case, one is perhaps hardly justified in predicting that, in their later development, the Ustilagineæ proper are likely to have ascorporic forms like Ustilaginoidea. It is a conceivable supposition, to say the least, that Ustilagineæ are a heterogeneous group and that when more is known of their development, they may prove to be imperfect conditions of more than one order of higher fungi. W. G. F.

11. *Die Entwickelung des Peritheciums bei Sphaerotheca Castagnei.* By R. A. HARPER (Bericht. Deutsch. Bot. Gesell., xiii, 475–481, Pl. 39).—More than twenty-five years ago DeBary advanced the opinion that the perithecium of Sphaerotheca and its allies is of sexual origin. At that time botanical technique was very different from what it is at the present day, and DeBary did not attempt to show that there was an actual union of the nuclear elements of what he considered to be the male and female organs. More recently there has been a tendency among mycologists to regard the sexuality in this case as doubtful or even disproved. In the present paper, the author, making use of the best modern manipulations, confirms the general account of the origin and nature of the antheridium and oogonium originally given by DeBary, and describes and figures the union of the nuclei of the male and female organs, adding important details with regard to the development of the perithecium from the oogonium. The fertilized nucleus of the female does not develop further until the ascogonium is surrounded by an envelope of two layers. The ascogonium then elongates and curves away from the side where the antheridium was attached. The nucleus now divides into two, and a transverse wall divides the ascogonium into two cells, the lower of which does not develop farther. The nucleus of the upper cell divides again and the process is repeated until a more or less curving row of five or six cells is formed. Each cell of this row contains a single nucleus except that next to the terminal cell, which has two nuclei and becomes the ascus. The ascus then enlarges strongly on the upper side, pushing the terminal cell sidewise and downwards until it is finally absorbed and disappears. The two nuclei of the ascus now fuse, but the author does not consider this to be a sexual act but another instance of the nuclear fusion known in asci and basidia. Finally the large nucleus divides three times and there are formed eight spores. W. G. F.

DR. JOHANN MÜLLER (known as Müller Argoniensis), died at Geneva Jan. 28, in his 68th year. He was the Director of the Jardin Botanique and Custodian of the Delessert Herbarium. He was distinguished as a Lichenologist, and also wrote the Euphorbiaceæ of DeCandolle's Prodromus.

III. Miscellaneous Scientific Intelligence.

1. *Catalogue of Scientific Papers (1874–1883). Compiled by the Royal Society of London*, vol. xi, 902 pp., 4to. London, 1896 (C. J. Clay & Sons, Cambridge University Press).—The present issue completes the series of three volumes forming the Supplement to the Royal Society's Catalogue of Scientific Papers for the years 1874–1883. The first volume (vol. ix) was noticed in vol. xxxiv (p. 170) of this Journal. The unique value of this work as a whole is too well appreciated to need commendation here. It gives under the name of the authors, arranged alphabetically, the full titles of papers wherever published, with the original references. This labor has been performed with much thoroughness and accuracy; the work should have a place in every scientific library.

2. *The Yellowstone National Park*, by Capt. H. M. Chittenden, U. S. A. 8°, 397 pp., 1895 (Clarke Co., Cincinnati).—This work will be found a most useful book of reference for the national wonderland. The history of the park and its early exploration will be found quite exhaustively treated. Other chapters treat briefly of its topography, geology, natural wonders, fauna and flora, etc. An excellent descriptive itinerary is given for travellers. The work is an excellent specimen of typographical art and is embellished by a large number of reproductions of beautiful photographs. The appended map, while very complete, is, however, a very poor specimen of typographic work and the only blemish we have noticed. L. V. P.

3. *Mechanics and Hydrostatics: an Elementary Text-Book, theoretical and practical*, by R. T. Glazebrook, M.A., F.R.S., pp. 652, Cambridge (Cambridge Natural Science Manuals); New York (Macmillan & Co.).—The crucial test of a treatise on Elementary Mechanics is the amount of vagueness and inconsistency to be found in the pages devoted to the discussion of force relations. To secure the requisite degree of simplicity without narrowness, and of logic without intricacy calls for much of the equipment of the philosopher, historian, physicist and practical teacher. Professor Glazebrook has succeeded in this, and *à fortiori* in the other parts of his work, not only because he possesses these qualifications but also because the numerous text-books on elementary mechanics which have appeared in the last ten years, though individually faulty, have collectively raised the treatment of the subject to a level where a text-book that is good throughout becomes possible.

The subject is developed experimentally and historically with an unusual fullness of discussion of difficult points and numerous detailed solutions of typical problems which will materially lighten the labor of teaching and economize the time spent in the class room. The author has judiciously avoided the use of most of the various new-coined words, such as velo, celo, and the like,

of which such a prolific crop has sprung up of late years. Velocity is treated as a vector, but the distinction between speed and velocity is in several cases somewhat carelessly disregarded.

4. *The Constitution and Functions of Gases, the Nature of Radiance, and the Law of Radiation.* By SEVERINUS J. CORRIGAN. St. Paul, 1895, pp. 128, and Supplement, pp. 46.—This is a restatement and enlargement of the author's hypothesis of the constitution of matter, first given in *Astronomy and Astrophysics*, Nos. 101 and 102 (1892). Two equal atoms are assumed to revolve in a circle about the middle point of the line joining them. The orbital velocity of atmospheric atoms of normal pressure and temperature is found to be 550,521,646 miles per second. A great number of atomic couples are regarded as forming a spherical shell, or hollow ball, and this constitutes a molecule of any gas. In a normal atmospheric molecule the number of atoms is found to be $2{\cdot}8943 \times 10^{14}$. The luminiferous ether is a rarified gas. From such a hypothetical constitution of gases the author develops the laws of radiation of light and heat.

5. *Algebra for Beginners*, by H. S. HALL and S. R. KNIGHT; revised for American schools by Prof. F. L. SEVENOAK. (Macmillan & Co. Price 60 cts.)—A text-book designed to meet the wants of those who do not require a knowledge of algebra beyond quadratic equations.

6. *An Introduction to the Algebra of Quantics*, by E. B. ELLIOTT. Clarendon Press, 1895, 8°, pp. viii, 423.—The students of higher algebra will feel specially grateful to Professor Elliott for his systematized treatment of the additions made to this branch of mathematics by Cayley, Sylvester, Salmon, Clebsch, Faà de Bruno, Gordan, and others during the last fifty years. Though entitled an *Introduction*, it really calls for a considerable preliminary knowledge on the part of the reader, such as would be gained, for example, from BURNSIDE and PANTON'S *Theory of Equations.*

7. *Problems in Differential Calculus*, by W. E. BYERLY. (Ginn & Co.)—An excellent collection of problems designed to accompany Prof. Byerly's Differential Calculus, but valuable in connection with any such treatise. It includes also problems in simple integration and in mechanics.

8. *Plane and Solid Geometry*, by Professors W. W. BEMAN and D. E. SMITH. (Ginn & Co.)—The work covers the subjects in geometry taught in the best American High Schools. There is a good index, also a biographical table, and a table of etymologies.

9. *Computation Rules and Logarithms with Tables of other Useful Functions;* by SILAS W. HOLMAN; pp. xlv, and 73. (Macmillan & Co., 1896.)—The Introduction of this book gives in detail precepts for securing a required degree of accuracy in computations without unnecessary expenditure of labor. Four and five-figure tables of logarithms of numbers, of logarithmic sines, tangents, etc., follow. The arrangement is well adapted for instruction, and for subsequent use in work not requiring unusual accuracy. It is rare that six or seven-figure tables are needed in actual practice.